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REPORT

OF THE

Cochituate Water Board,

IN REPLY TO AN

ORDER OF THE CITY COUNCIL (PASSED OCT. 31st, 1873) RELATING TO THE AVAILABLE QUANTITY AND PURITY OF THE MYSTIC WATER AND TO OTHER MATTERS CONNECTED WITH AN ADDITIONAL SUPPLY FOR BOSTON.

BOSTON:
ROCKWELL & CHURCHILL, CITY PRINTERS,
122 WASHINGTON STREET.
1874.

CITY OF BOSTON.

Office of the Cochituate Water Board,
Boston, January 7th, 1874.

To the City Council of the City of Boston: —

In compliance with the order of the City Council of Oct. 27, 1873, requesting the Cochituate Water Board to investigate and report upon the following matters: — "The present condition of water in Mystic pond, as regards quantity and purity; the approximate cost of obtaining a supply from said pond for the City of Boston; the objections, if any, to relying upon the same as a source of supply; the condition of the present conduit from Lake Cochituate, as regards capacity and safety; and the changes needed to prevent any waste of the present supply; —" the Board asks leave to reply: —

That its attention was called to the Mystic pond as a source of supply for this city some two years since by their Engineer (See City Doc. No. 29, 1873), but after due consideration it was dismissed from the list of practicable sources, which the Water Board thought its duty to recommend to the City Government; but, after the receipt of the above order of inquiry, and recognizing the wide differences of opinion existing in the community, as to the quality of the water as well as to the capacity of the Mystic basin as a source of *permanent* supply for the City of Boston, the Board, as a matter of justice to itself and its engineer, has thought it judicious and proper to have the whole subject

1874

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investigated independently, by thoroughly competent persons, so that, after the investigations were closed and the facts presented, the questions should be definitely settled in every reasonable mind. With these views, the services of two eminent hydraulic engineers, Mr. James P. Kirkwood, of Brooklyn, N. Y., and Mr. James B. Francis, of Lowell, Mass., were secured as an Engineering Commission, and the Board was equally fortunate in securing Prof. E. N. Horsford, of Cambridge, to investigate as to the purity of the water. All these investigations, and the results, will be found in their reports, in the succeeding pages of this document, and are worthy of the careful attention of the City Council, and of citizens generally. The facts given with regard to the Mystic basin are in close approximation to the information that was already in possession of the Board, from the report of its engineer (the present City Engineer), and stated in general terms in the City Document above referred to, and show not only that the extravagant claims made for this basin as a source of permanent supply were, in a large degree, unfounded, but that an imperative duty exists for the city to take the most effectual means for securing that supply from some other and more practicable source, for its rapidly increasing territory, population and industries, at the earliest moment.

COMBINED SUPPLY FROM THE COCHITUATE AND MYSTIC.

The report of Messrs. Kirkwood and Francis states, that by utilizing (at an expense of $994,562 for storage reservoirs) all the available storage capacity of the Mystic basins, including the lower Mystic lake, a total supply of 18,000,000 gallons daily may be secured, and that a more moderate expenditure for reservoirs will provide a supply from which a surplus of about 5,000,000 gallons may be applied to the use of Boston, until 1880 or thereabouts, when the increasing demands of Charlestown and East Boston,

and the towns depending upon the Mystic works, will begin to curtail it. It is also stated, that the Cochituate conduit should not be relied on "to convey more than 17,000,000 gallons in any one day." These statements should be considered together, in computing the total supply available to Boston for the next few years.

The consumption in Boston during 1873 was about 18,000,000 gallons daily, and largely in excess of the previous year, due partly to a reckless use of hand-hose, leakage in the burnt district, and an increased head in portions of the city, as well as to the increased number of water-takers. The consumption is very unequal in different months, and to maintain the supply during the summer months it was found necessary to use the conduit under a pressure that would give a flow of over 20,000,000 gallons in twenty-four hours, and even then the reservoirs were drawn down to a point that reduced materially the water held in reserve to supply the city in case of accident to the conduit. If the maximum flow of the conduit is to be limited to 17,000,000 gallons in twenty-four hours, the supply will not on an average much if at all exceed 15,000,000 gallons daily. To operate the Cochituate Works *safely*, an additional supply of 3,000,000 gallons daily is required at once; and the supply which can be safely obtained from the Cochituate Works, combined with that which may be secured from the Mystic (some two years hence), will give an excess of only 2,000,000 gallons daily, above the use of the past year, to meet the future increase in consumption, which will follow from increase of population, by natural growth and by annexation. By using all the storage area offered by the Mystic basin, this excess may be increased to some four or five millions, an amount which, at the rate of increase in water-takers that has ruled for the past few years, will be absorbed in four or five seasons.

If the conduit is to be operated as it was found necessary to operate it the past year, — in a manner which it is proper

to say, the Water Board and its officers consider decidedly unsafe, — the excess will be further increased by about three millions of gallons. This is upon the supposition that the Cochituate water-shed will yield a supply of 18,000,000 gallons daily; but the fact is, it cannot be relied upon to do so. The following table exhibits the total quantities of water, stated in daily averages, that entered the lake from its water-shed during various years, and of which in some years a large portion was necessarly wasted over the dam during floods: —

Year.	Gallons per day.	Year.	Gallons per day.
1853.	17,873,800.	1858.	17,759,013.
1860.	17,714,065.	1864.	15,370,152.
1866.	14,265,280.	1871.	13,197,800.

The yield of the Cochituate water-shed in a season of extreme drought has been estimated by the City Engineer, Mr. Jos. P. Davis, at 12,000,000 gallons daily; but, as seen above, in 1871, which cannot be considered such a season, it actually was only 13,197,800 gallons. Add to this the 5,000,000 gallons that may be taken from the Mystic, and there is 18,000,000 gallons, just equal to the consumption of the past year, 1873. To state the case plainly, and it does seem that the time has come to so state it, this city will be dependent upon good fortune, that is, upon heavy rains and freedom from accident to the works, for a full supply of water, during the next few years, even if the Mystic be drawn upon, unless an auxiliary supply is taken from the Sudbury river, as in 1872. As matters now stand, the city has no rights in the Sudbury river, and would unquestionably be prevented by the mill-owners and others interested, from again drawing from it unless the river is legally seized under the Act of the Legislature authorizing the taking. If it be decided to abandon the Sudbury river project, the city will be forced to rely upon the Cochituate and Mystic districts,

from which, by an expenditure of some one and a half millions of dollars upon the latter, in two years a total daily supply of about 22,000,000 gallons can be furnished; *provided* that the rainfall is favorable, and the Cochituate conduit is operated under objectionable pressure during the months of greatest consumption.

THE SUDBURY RIVER.

During the early months of 1872, while the pumping engines were at work in Lake Cochituate, in consequence of the unprecedentedly low state of the water, application was made by the city to the Legislature for power to take water from an independent source of supply; and the Water Board was informed by the legislative committee that it must limit itself to two sources, though the Board had asked for a general act with the design of selecting the best source, after a careful study and survey of the whole question. A pretty thorough examination had been hurriedly made of the different available water districts within reasonable distance from the city, including the Ipswich and Saugus rivers at the north, the great lakes of the Middleborough district at the south, and the Merrimac river at the northwest. All these were rejected, however, either for their large cost, impurity of water, difficulty of connection with the present system of works, want of storage capacity, or insufficient amount of water for the needs of the distant future. The only course, therefore, was to look to the west, where were found the Charles, Sudbury, Assabet, and Nashua rivers and Lake Quinsigamond, which, combined, would give a daily supply of 220,000,000 gallons, and all of which could be brought to Chestnut Hill Reservoir in the same conduit. The Water Board selected the Charles and Sudbury rivers; but during the hearing before the legislative committee, a strong and decided opposition was made to the taking of the Charles river, except upon such con-

ditions and restrictions as were entirely inadmissible; and therefore, upon the promise of the committee to report a favorable bill for the Sudbury, the Charles was dropped and a bill for the Sudbury was reported and passed by the Legislature. Doubtless the facility with which the water of the river could be turned into Lake Cochituate to supply a pressing temporary want in that basin had some considerable weight in the selection; but careful study and survey of its capabilities as a source of permanent supply revealed facts of a very favorable character. These were: The large amount and good quality of the water; its excellent storage facilities and easy control; comparatively moderate cost of construction, the shortness of the conduit line to Chestnut Hill Reservoir, the great point of distribution; and the comparative present and prospective freedom from pollution of the water-shed. Its combined value in all these essentials is such that the Water Board has seen no reason to regret its selection or doubt the wisdom of the choice. The rapidity with which its waters can be turned into the lake has already been proved at a time of some considerable public peril.

The Sudbury, with its ample storage basins, in a season of drouth will yield a minimum supply of 40,000,000 gallons daily, and in favorable seasons a supply of 50,000,000 gallons or more; should occasion demand in the future, it can be easily connected with the Assabet river, from which nearly an equal amount can be drawn, and the practicability of its connection with the other water districts named above is an equally assured fact. The connection with the Charles river would be by pumping works at South Natick, all the others by gravitation. In the Sudbury river scheme of works, not only has the needs of the immediate present been duly considered, but the future has been amply cared for.

Efforts seem to have been made to prejudice the Sudbury river scheme, by misrepresenting its cost, and the time re-

quired for its construction. It has been claimed that it will cost between twelve and fifteen millions of dollars, and that it cannot be completed short of ten or twelve years' time.

Those making these misrepresentations entirely ignore the careful and exhaustive surveys, and the liberal estimates founded upon them by our able and experienced engineers. The Water Board has no hesitation in saying, there is not the slightest foundation for such statements, that there is no reason for distrusting the professional skill of, or the facts and estimates given by the engineers, in their report as to the cost or the time required for construction; most certainly not upon the reckless statements of those having no practical experience in engineering works. So far as the amount of water or mill damages to be paid is concerned, the Board can only say that this matter will be determined before a Massachusett court and jury, and upon competent evidence as to the real amount of damage caused by diverting the water of the river; it has no fear but that the verdict will be an equitable one, and the damages not excessive. But it must not be forgotten that the City of Boston cannot take water from any practicable source without paying for it, and it is not at all probable that the cost will be larger, in proportion, for the Sudbury river, than for water taken from any other source.

When the present Cochituate conduit was constructed, it was generally considered that the city had secured an ample water supply for the next fifty years at least. But a little more than one-half of that period has passed, with the results which are now under consideration. The lesson is a very useful one, not only to the City Government, but to all concerned. After mature deliberation upon all the numerous questions involved in the general subject of securing a permanent and ample supply of water for domestic, fire, manufacturing, and other uses for a rapidly growing community like this, the Water Board finds ample reasons for again recommending the most energetic action for the construction

and early completion of the Sudbury river supply for the City of Boston. The adoption of any policy which shall restrict the supply of water for all legitimate uses, will be a mistaken and unfortunate one; and this will apply with great force to the territory recently annexed and that hereafter to be annexed, and with still greater force to the numerous manufacturing industries that are springing up in and near the city limits. The fear of an insufficient supply would tend to restrict and dwarf a great many industrial establishments in a very large degree, and possibly lead to their location elsewhere. The Water Board feels that a great and growing city like this cannot afford to endanger its progressive prosperity by failure to take the proper action to secure its continuance.

FLAX POND.

In passing, it may be well to take some notice of the persistent efforts which have been made through the public press (probably by interested parties) to induce the taking of Flax pond, in Lynn, as a source of supplementary supply for this city. This source had already been examined and rejected, because of its small area of water-shed; the pollution of the water by the objectionable refuse of manufacturing establishments; the large cost of construction of the works with reference to the amount of water to be obtained; the cost and difficulty of diverting the objectionable sewerage on its shores; and the uncertain amount of damages to be paid for diverting its waters. Subsequently, however, it was deemed advisable to refer the whole question of Flax pond to the engineers, Messrs. Kirkwood and Francis; and they have reported (see pages 24–27) that, in their opinion, it is inadvisable to add it to the present city supply; and for reasons that are nearly identical with those that first led to its rejection by this Board.

LEAKS AND WASTE.

The questions of waste and leakage have received more than ordinary degree of attention during the past year. The large consumption, ruling nearly through the whole year, is not only unexpected, but somewhat alarming. The Board had hoped by a thorough search for leaks both in the street-mains and house-service to reduce the consumption below that of 1872; or, at least, place the works in a condition that would result in an important saving during the present year. While many hundreds of defective fittings that were causing a large waste have been discovered and repaired, no leaks of consequence have been found in the street-mains; and, though the saving that has been effected by the repairs made must be considerable, the consumption of the past two or three months shows that not much relief can be counted upon from stopping leaks.

The examination that has been made, however, has furnished additional evidence of the great *waste* that results from the use of certain classes of fittings, more particularly the hopper-closet. Attention has been frequently called to this matter in former reports, but no action has been taken by the City Council. It is to be hoped that now, when it is of the utmost importance to the city that every gallon of water it can furnish shall be usefully applied, the necessary powers will be given the Water Board to control, as far as practicable, the harmful waste that is now going on through improper fittings. In many instances, as has been proved by meter measurements, the owners of a single hopper-closet are using, or rather wasting, at a cost to them of only *five dollars* per annum, as much water as the manufacturer uses whose yearly water-rate amounts to some hundreds of dollars. This great waste subserves no sanitary or other useful purpose, and should at once be repressed by the most vigorous measures. Even if the saving of water were not so important, the injustice of such unequal taxation would con-

demn the present system. This very important matter is more fully discussed in the annexed report of Mr. Wm. F. Davis, the Water Registrar, to which you are referred for more detailed statements.

ANALYSES OF THE WATER OF FARM POND, SUDBURY RIVER, AND LAKE COCHITUATE.

An order was passed by the City Council, November 10th, 1873, requesting the Water Board to have made a chemical analysis of the waters of Farm pond. In complying with the request, the Board has also had analyzed a sample taken from Sudbury river, another from its most important tributary, Stony brook, and two from Lake Cochituate.

The analyses, the results of which are given in the following table, have been made by Messrs. Merrick and Gray, analytical chemists, who had no knowledge of where the samples were taken : —

	A Stony brook.	B Sudbury river.	C Farm pond. Surface	D Farm pond. 7 ft. deep.	E Lake. near gate house.	F Lake. Southern division.
	Grains in U. S. gal.	*Grains in U. S. gal.*	*Grains in U. S. gal.*	*Grains in U. S. gal.*	*Grains in U. S. gal.*	*Grains in U. S. gal.*
Suspended matter	0.48	0.31	0.23	0.15	0.24	0.40
Inorganic	2.10	2.39	1.98	1.75	1.87	2.26
Organic	1.69	1.80	1.16	0.99	1.10	1.92
Total	4.27	4.50	3.37	2.89	3.21	4.58
Silica, oxide iron, alumina, etc.	0.73	0.70	0.54	0.38	0.40	0.70
Chlorine as Chloride Sodium	0.35	0.40	0.35	0.35	0.32	0.30
Albuminoid Ammonia . .	0.0147	0.0139	0.016	0.013	0.012	0.015
Ammonia	0.003	0.004	0.004	0.0041	0.005	0.004
	0.0177	0.0179	0.02	0.0171	0.017	0.019

All the samples were taken Nov. 7th, 1873.

Sample A was taken from Stony brook, about 500 feet above the proposed location of Dam III.

Sample B was taken from Sudbury river, about 200 feet above the wooden dam, built by the city in 1872.

Sample C was taken from the surface of Farm pond, about 400 feet north of the proposed location of the gate-house for the new conduit.

Sample D was taken at the same point in Farm pond, but 7 feet below the surface.

Sample E was taken from Lake Cochituate, near the gate-house of the conduit.

Sample F was taken from the southern division of Lake Cochituate, at the culvert under the turnpike, and near where Beaver Dam Brook (the chief tributary of the lake) discharges.

Mr. Merrick makes the following remarks: —

Sample A.

"This water was yellowish, inodorous, tasteless, with some slight flocculent deposit after standing. The unconcentrated water gave indications of ammonia by the Nessler test."

Sample B.

"This sample was yellowish, tasteless, inodorous, with some flocculent deposit on standing. It gave slight indications of free ammonia by the Nessler test."

Sample C.

"This sample was nearly colorless, tasteless, and inodorous, with a very slight flocculent deposit after standing. It gave exceedingly faint indications of ammonia, unconcentrated."

Sample D.

"This sample was colorless, or nearly so, inodorous, and giving a trifling deposit on standing. It gave very faint indications of ammonia."

Sample E.

"Nearly colorless, with faint, yellowish tint, inodorous; some deposit of reddish flakes. It gave exceedingly faint indications of ammonia."

Sample F.

"This water was yellow, inodorous, and tasteless, with considerable flocculent deposit. The unconcentrated water gave indications of the presence of ammonia by the Nessler test."

The analyses show Farm pond water to be very pure and free from objectionable qualities of all kinds. There had been no flow into the pond, except surface drainage, for over a year before the samples were taken, and the outflow had been very slight, just sufficient to keep the pond at a proper level.

The two samples from Cochituate were analyzed to show the effect of storing and exposure to the air in purifying the water. Sample F may be regarded as a fair (favorable rather than otherwise) specimen of the quality of the water from the Cochituate water-shed as it enters the lake. Sample E — a fair specimen of the same water after it has reached the entrance to the conduit.

EFFECTS OF STORAGE ON WATER.

It will be noticed, by consulting the table, that the effect of storing has been to greatly improve the quality of the waters, and to notably decrease the amount of organic matter, which is the impurity the most to be feared; in fact, the inorganic impurities may be said to be perfectly harmless.

This beneficial effect of storing and exposure is more strongly shown in the samples of water from the Mystic, analyzed by Professor Hosford, as will be seen by consulting his report. The waters tributary to the Mystic are vastly more charged with impurities, both mineral and organic, than those of the Cochituate or Sudbury water-shed; yet, during the exposure to the air to which they are subjected on entering and passing through the Mystic lake, they become purified and rendered fit for domestic use.

The samples from the Sudbury valley were taken when the river was swollen by previous rains, and the water more than usually charged with organic or vegetable matter, yet the analyses show very favorably for the purity of this water when compared with that of the Cochituate or Mystic districts before it enters the lakes.

It can be safely said that the Sudbury water, after having been stored, and by the time it reaches the consumer, flowing, as it will, exposed to the air in Farm pond and 17 miles of conduit, will be nearly, if not quite, equal in purity to the Cochituate.

That all the points bearing upon this question of purity, which are known to the Board, may be placed before you, the following remarks from the Report of the City Engineer, submitted to you in March, 1873, are quoted: —

"Previously to the selection of the Sudbury as the new source for the additional supply, no analysis of its water had been published or was at command. There were, however, various reasons for believing that it is unusually free from deleterious matter either in solution or held suspended. Such was the testimony of all persons consulted, who had observed and used it. It is used, as taken from the river, in all the processes of bleaching, and is noted for its fitness for the purpose, which would indicate that it is generally free from color, and from matter in suspension. The country drained is of a character to insure purity of supply; it is for the most part very sparsely populated, contains few or no

soluble rocks or earths, has quick drainage slopes that are not much cultivated, and maintains on its streams comparatively little manufacturing of an objectionable nature. After heavy rains in the summer and fall, when the drainage surfaces are covered with dead and decaying vegetable matter, the waters of rivers draining cultivated districts, or districts covered with forests and grasses, unusually become more or less colored by such portions of this vegetable matter as are readily taken up in solution, or as have been washed into the streams and are held in minute forms, mechanically suspended.

"The conditions in regard to the frequency of the rains and the amount of vegetable substances in a ripe state to be acted upon, that have obtained during the past summer and fall, have been such as to develop and maintain a high color in river waters generally. Owing to the dryness of the previous year, there has been an unusual accumulation of vegetable matter ready to be taken up, either in solution or suspension, and there have been constantly recurring rains of a magnitude to produce a complete saturation of this matter, and a flow over the land surfaces to the streams. All the streams in this part of the country appear to have been affected to an unusual degree. The color began to be noticeable in the Sudbury water early in July, and continued in a marked degree till near the close of the year. It was of sufficient intensity to render the water, as taken directly from the river, unfit for washing and many other purposes.

"Samples were taken when it was at its worst state, and submitted to chemists for analysis. The following are the results obtained.

"Analysis by Dr. S. D. Hayes of Boston: —

Specimen A.

Organic matter	4.08 grains.
Mineral "	1.64 "
Total of impurities in one gallon . .	5.72 "

"Dr. Hayes adds, 'Specimen A is brownish yellow and almost brandy-colored: it contains $4\frac{8}{100}$ grains of purely vegetable matter,

like that obtained by soaking leaves having a high tinctorial power. This water is objectionable from its color and the comparatively large proportion of vegetable matter present, but it is free from animal matter or dangerous drainage.'

"Analysis of Professor Chandler, of New York: —

Specimen A.

Organic and volatile matter . . .	2.03	grains.
Inorganic	2.93	"
Total solids in one gallon . . .	4.96	"

"The fact is made evident in the above analyses that there may be present, at times, a large and objectionable amount of organic matter of vegetable origin, and while it is not probable that the conditions which have caused this state of the water will again exist in an equal degree, except with long intervals, it is nevertheless important to be assured that when they do exist the water can be made fit for general use.

"In 1867, commissioners were appointed to investigate the question of proper sources of supply for London and other large cities, before whom were summoned a great number of prominent chemists, and other scientific men, to give their views upon impurities in water. The commissioners, in their report, say: —

"'The organic compounds dissolved in water appear to be of very instable constitution, and to be very easily decomposed, the great agent in this decomposition being oxygen, and the process being considerably hastened by the motion of the water. Now, as such waters (river waters) always contain naturally much air dissolved in them, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water, in addition to which, motion causes a further action by exposure to the atmosphere. . . . The effect of the action of oxygen on these organic matters, when complete, is to break them up, to destroy all their peculiar organic constitution, and to rearrange their elements into permanent inorganic forms, innocuous, and free from any deleterious quality. It does not follow that all organic matter in water is prejudicial, . . . almost all our drinks, other than water, owe their distinctive qualities to the varieties of their organic contents.'

"Dr. Lyon Playfair, Professor of Chemistry in the University of Edinburgh, in his testimony before the commissioners, states: —

"'The effect of organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water originally is of a pale sherry color, on being exposed to the air in reservoirs, or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air, and becomes insoluble, and is chiefly deposited; and what remains has no influence on health.'

"From our own experience in the use of the Sudbury water last summer and fall, when, as taken from the river, it was highly colored, and from some experiments since made, there are strong reasons to believe that the effect of storage in large reservoirs, and of the exposure to air in a long conduit running but partially full, will be to in part or wholly decompose the organic impurities, and destroy the color. In July and August the Sudbury water was entering Lake Cochituate at the rate of from twenty to thirty millions of gallons per day, and in addition a large supply was received from the streams naturally tributary to the lake, which possessed an equal color with that of the Sudbury water; yet when these waters reached the pipes for distribution, no color was noticeable, and the slightly bitter taste, which they originally had, was lost.

"The gradual extinction of the organic matter is shown by an examination of the following table, which gives the results of analyses of three samples of water taken; the first from the Sudbury at the new dam; the second from the southern division of the lake, where the supply from the Sudbury and from Beaver Dam brook (the most important tributary to the lake) entered, and the third from the northern division, near the mouth of the conduit.

By whom analyzed.	*Specimen A.* Impurities in grains per gallon.			*Specimen B.* Impurities in grains per gallon.			*Specimen C.* Impurities in grains per gallon.		
	Mineral	Organic	Total.	Mineral	Organic	Total.	Mineral	Organic	Total.
Dr. Hayes	1.64	4.08	5.72	1.68	2.40	4.08	1.65	1.71	3.36
Prof. Chandler	2.93	2.03	4.96	2.45	1.40	3.85	1.87	0.81	2.68

"The remarks of Dr. Hayes upon specimen A have already been given; with reference to the other samples he says: —

"'Specimen B is also tinted brownish-yellow, and has the characters of specimen A, but in a lesser degree. This water is as pure as that supplied to several cities in New England.

"'Specimen C is almost colorless and tasteless. It is a very pure water for drinking and all household purposes. Although the proportion of vegetable matter present is larger than could be desired, it is not of an objectionable kind.'

"Sudbury river water, stored in Farm pond, after its connection with the river was shut off in the fall, and also when kept in bottles loosely corked, was found to grow lighter in color from day to day, although it still maintained its deep tinge in the river itself.

"Messrs. Merrick and Gray (analytical chemists) made an analysis of a sample taken in December last, when the river still had a decided tinge not usual to it, and found 3.23 grains of impurities of all kinds, to each U. S. gallon, of which 1.34 grains were organic matter. These amounts are somewhat less than were found by Dr. Hayes, in his analysis of specimen C, taken from Lake Cochituate during last summer, and they would, beyond doubt, be greatly reduced by storage of the water and long exposure to the air.

"The Cochituate water was received in the city in a clear and perfectly acceptable state, and was pronounced by Dr. Hayes as very pure for drinking and all household purposes. From a sanitary point of view, the harmless nature of vegetable matter in water, unless in large quantities, is generally conceded. The testimony of chemists before the commission, already quoted, was unanimous on this point. Its great objection is the slightly bitter taste it sometimes imparts, and the brownish color it produces, a color which renders the use of the water for domestic purposes disagreeable.

"From the facts before us the conclusions may be drawn, first, that usually the water of the Sudbury river is clear and pure, and well suited for a domestic supply; second, that although subject, like all rivers, to temporary impurity of a vegetable origin, that impurity may be reduced to a harmless and inappreciable quantity by exposure to the air in storage basins and the conduit."

The accompanying very elaborate report of Prof. Horsford, on the purity of the water of the Mystic basin, is commended to your careful attention.

CONDITION OF THE COCHITUATE CONDUIT.

A very thorough examination of the whole length of the conduit has been made by skilled experts familiar with such structures, and the details of the examination, reported by Mr. D. W. Cunningham, First Assistant Engineer of "New Supply," are herewith presented for your consideration. While the conduit will be operated with great care and closely watched, and while there is but little fear of disaster happening, yet measures have been already taken to meet any break in its weaker points by the construction of wooden flumes, ready to be applied at once at any exposed point; so that if any break should occur it can be repaired in the shortest possible time. While the condition of the conduit is and has been for the past year a constant source of anxiety to the Board, it trusts, by extra care and watchfulness, to avert any serious disaster that may imperil the uninterrupted flow of Cochituate water to the city.

In conclusion, the Board has the pleasure of stating that the income for water is steadily increasing from year to year, the receipts of the past year showing an advance over those of the previous year of over one hundred and seven thousand dollars.

For the Cochituate Water Board,

JOHN A. HAVEN,

President.

ERRATA.

Page 9.—Sixth line, for *widely*, read *rudely*.
" 9.—Sixteenth line, for *plank*, read *flash*.
" 9.—Twentieth line, for *plank*, read *flash*.
" 12.—Fifth line of Table, for 100, read 60.
" 15.—Fifth line, for *storage*, read *drainage*.
" 16.—Second line from bottom, for 1882, read 1880.
" 18.—Sixth line, for *cubic*, read *lineal*.
" 19.—Eleventh line, for *colorless*, read *soft*.

CITY OF BOSTON.

Boston, December 11, 1873.

John A. Haven, Esq.,

President Cochituate Water Board: —

Sir, — The order of the Board of Aldermen of October 27th, 1873, to which you have referred us, requests the Cochituate Water Board to furnish information to the City Council upon the following points, viz.: "the present condition of the water of Mystic pond, as regards quality and purity; the approximate cost of obtaining a supply from said pond for the City of Boston; the objections, if any, to relying upon the same as a source of supply; the condition of the present conduit from Lake Cochituate, as regards capacity and safety; and the changes needed to prevent any waste of the present supply."

We ask your attention first, to the Mystic lake and its water-shed, confining ourselves first to the quantity, without reference to purity, which can be relied upon as obtainable from that basin.

This quantity is ruled by the annual flow of water from the basin during a very low season of rainfall, unless the ground admits of such a capacity of storage reservoirs as will allow of the waters of a wet season being held in reserve to supplement a dry season, which is rarely the case, and not practicable in the Mystic water basin. If we predicate the available water upon any other than the delivery of a very dry season, we run the risk of exposing the communi-

ties depending on it to a lack of water during the exceptional seasons which so certainly occur at, it may be, long intervals; and to the distress and distrust following such a condition of the water supply.

There is a considerable population now depending upon the water of this valley, whose rate of growth and increased consumption of water it is desirable to understand in this connection.

The places now using the water, in connection either with the Charlestown Water Works, or with independent works of their own, are as follows: —

Charlestown,	Population	in	1870,	28,323
Somerville,	"	"	"	14,685
Chelsea,	"	"	"	18,547
East Boston,	"	"	"	25,484
Everett,	"	"	"	2,220
Revere,	"	"	"	1,197
Woburn,	"	"	"	8,560
Winchester,	"	"	"	2,645
Total,				101,661

The growth of this population must be assumed rather as a matter of judgment, than from any data derivable from the statistics of the past thirty years, for the decennial percentage of increase during that time, as the following table will show, is very irregular. The populations of Woburn, Winchester and that neighborhood have been considerably increased by the many and important tanneries established there, which are very likely to go on increasing regularly with the growth of the country. The populations of Charlestown and East Boston might be expected to sympathize with the numerical increase of Boston, but yet within the last thirty years they seem to have increased in a much higher ratio.

The percentages of increase of the Woburn and Winchester populations from 1850 to 1860 were respectively 58.9 and 43.2, while the increase of Charlestown during the same period was 45.6, and East Boston, 71.7.

	Charlestown.	East Boston.	Somerville.	Chelsea.	Everett.	Revere.	Woburn.	Winchester.	Totals.	
1840.	11,484	6,000	2,000	2,390	. . . . . .	. . . . . .	2,993	. . . . . .	24,867	1840.
Per cent. increase .	49.91	64.95	77.00	180.37	. . . . . .	. . . . . .	32.17	. . . . . .	71.56	Per cent. increase.
1850.	17,216	9,897	3,540	6,701	. . . . . .	. . . . . .	3,956	1,353	42,663	1850.
Per cent. increase .	45.59	71.68	126.69	99.89	. . . . . .	. . . . . .	58.92	43.17	68.06	Per cent. increase.
1860.	25,065	16,991	8,025	13,395	. . . . . .	. . . . . .	6,287	1,937	71,700	1860.
Per cent. increase .	13.00	49.98	82.99	38.46	. . . . . .	. . . . . .	36.15	36.55	41.78	Per cent. increase.
1870.	28,323	25,484	14,685	18,547	2,220	1,197	8,560	2,645	101,661	1870.
1860.	25,065	16,991	8,025	13,395	. . . . . .	. . . . . .	6,287	1,937	71,700	1860.
Per cent. increase .	5.32	21.05	16.55	7.52	. . . . . .	. . . . . .	11.32	1.60	11.14	Per cent. increase.
1865.	26,399	20,568	9,353	14,403	. . . . . .	. . . . . .	6,999	1,968	79,690	1865.
Per cent. increase .	7.28	23.90	57.01	28.77	. . . . . .	. . . . . .	22.30	34.40	27.57	Per cent. increase.
1870.	28,323	25,484	14,685	18,547	2,220	1,197	8,560	2,645	101,661	1870.

The period between 1860 and 1870 gives an exceptional indication of the progress of the populations, because the war checked seriously its increase in New England, and in some places, as at Lowell, showed a reduction in the population of 1865 as compared with that of 1860; but after 1865 the enterprise of the country was rapidly recovering itself, and the increase of the population then would come nearer to the conditions of a natural and healthy growth. The increase during this period of five years was for Woburn, 22.3 per cent.; Winchester, 34.4 per cent.; Somerville, 57.01 per cent.; Charlestown, 7.28 per cent.; East Boston, 23.9 per cent.

If we take the last decennial rate of increase of the entire population of the places referred to as some guide to its rate of increase in the future, it will be erring on the side of moderation, since that period includes the years of the war already alluded to.

This	increase	between	1840	and	1850	was	71.56	per	cent.
"	"	"	1850	"	1860	"	68.06	"	"
"	"	"	1860	"	1870	"	41.78	"	"

Throwing off the period between 1860 and 1865, when the increase was but 11.14 per cent., we have for the period between 1865 and 1870, a rate of increase in five years of 27.57 per cent.

The decennial increase of the City of Boston was, for the ten years before the war (1850–1860), 29.92 per cent.; for the ten years including the war (1860–1870) it was but 17.76 per cent.

Without being able to extract from the above statements any rate of increase which would be entirely acceptable, we will assume a decennial increase of 40 per cent. as moderate and reasonable for the aggregates of the populations of the places enumerated, between 1870 and 1890; reducing the

rate to 35 per cent. between 1890 and 1900, and to 30 per cent. thereafter. These rates are lower than the tabular figures above given may seem to warrant, but we have to keep in view that as the population increases the rate of growth usually decreases; and, besides, we are aiming at moderation in a statement which does not admit of nice computation.

The following table exhibits the condition of the population under this assumption up to 1910, and the corresponding consumption of water at the rates of 60 and 70 gallons a head: —

Aggregate population of the eight places enumerated.		Probable consumption of water at 60 and 70 gallons per head.	
		70 gallons per head.	60 gallons per head.
1870	101,661		
Increase taken at 40 per cent.			
1880	142,325	9,962,750	8,539,500
Increase taken at 40 per cent.			
1890	199,255	13,947,850	11,955,300
Increase taken at 35 per cent.			
1900	268,994	18,829,580	16,139,640
Increase taken at 30 per cent.			
1910	349,692	24,478,440	20,981,520

The rate of 60 gallons a head would usually be considered liberal, except where there is much shipping, or much wharfage likely to be well occupied in the future by ships and steamers. In the last case even 70 gallons a head is found inadequate. We have added the rate at 70, because the results given by the 60-gallon rate would soon be overreached, if the annual increase in the consumption of water, shown by the reports of the Mystic Water Board, is to continue to follow the same proportion.

The average consumption per diem was : —

In 1870,	3,849,575	gallons.
" 1871,	5,082,972	"
" 1872,	6,766,056	"

In 1880, according to this rate of progress, the highest figures given for that year, in the table, would be exceeded, but much may be done in the future to save that portion of the water which is now wasted at neglected joints and fittings. It is to be observed of 1870 that the population given in the table for that year includes three places which were not supplied with water then; when the necessary deductions are made and the rate of 60 gallons a head applied to the population using the water that year, the result but little exceeds the reported consumption of 3,849,575 gallons per diem.

We come now to the quantity of water derivable from the Mystic basin.

The percentage of the rainfall which flows off, or can be collected from any basin, varies with the climate, and with its position, and its geological character; of the rain falling during the summer months, June to October, comparatively little reaches the brooks.

The rain of the winter and spring months, November to May, reaches, in large part, the brooks, and forms our main dependence for storage.

The only records of the rainfall on the Mystic water-basin are those kept at the Mystic lake. For 1870 and 1871 the rainfall there was unusually low, and were these data true of the entire basin it would be difficult, if not impossible, to count on 12 inches of the amount during equally low seasons, except by having the ability to make a wet year contribute to the supply; that is, to be able to combine the flow of three years so as to be ahead of the supply of two such low years

as this record exhibits. But in the upper portions of the basin, towards its high grounds, a greater depth of rain had very probably fallen.

In the following table there is added the rainfall at Cambridge, Lowell, Lake Cochituate, and Boston, going to show that the Mystic lake station, if correctly observed, gave for these years, at least, exceptionally low results. If, however, we look back to the returns of other places in the vicinity of Boston, we find one year which may be taken as a warning, when the rainfall that prevailed was unusually low, and being well corroborated cannot be set aside as growing out of erroneous observations.

In 1846,	the rainfall	at Boston	was	29.95
"	"	" Waltham	"	26.90
"	"	" Lowell	"	28.03
"	"	" Cambridge	"	30.37

These are sufficient to show that a very small amount of rain fell in that year, but luckily the years on either side of it were much more abundant in that respect.

In 1822, at Boston, the record gives but 27″.20 of rain; in 1837, at Lowell, 30″.86; in 1855 the lowest of the Cochituate series is 34.96. From all of these we see that the lowest rainfall will sometimes be below 30 inches, though we have no record below 26.90, except those of 1870 and 1871, at Mystic lake, given below.

Table of rainfall for 1870–71–72: —

	1870.		1871.		1872.	
	The twelve months.	Seven mont's Nov. to May.	The twelve months.	Seven mont's Nov. to May.	The twelve months.	Seven mont's Nov. to May.
Mystic Lake	24.65	16.09	24.36	13.28	45.05	13,99
Cambridge Observ'y.	41.53	28.90	40.50	22.37	52.73	21.68
Lowell	48.70	32.28	44.15	25.16	48.66	23.36
Lake Cochituate . .	50.65	32.51	48.29	29.71	45.74	18.29
Boston (South yard)	59.73	39.06	48.33	29.60	58.04	24.92

For the percentage of rainfall collectable from any basin we have to rely generally on the judgment of the engineer. Where, as at the Cochituate lake for the Cochituate basin, and at the Croton lake for the Croton basin, daily records have been kept of the depth of water flowing off, these, even when widely taken, afford some better measure of the water reaching the main streams than any estimate which would otherwise have to be formed of that amount, gathered from the averages of a long series of observations of rain-fall at places in the vicinity of or within the proper basin. Had the daily observations of the height and flow of water at the Mystic dam been made in such a way as to give correct results, they would have aided us to get a near value of the water reaching that point, to compare with the rain-fall observed there for 1870 and 1871; but on this dam, which consists of six spaces, the plank boards are not always maintained at the same level. The keeper is instructed not to allow the lake to rise above a certain fixed level; to insure this when a storm of rain occurs, encroaching on this fixed plane, he removes a plank board from one, two or more of these spaces, as the case may be, not recording, however, the depth flowing over at each separate space.

Since December, 1871, a fish-way has been in existence, by an act of the Legislature, occupying one of the six spaces above referred to, and passing, according to our calculations, a yearly average of, say, 423,000,000 gallons = 56,600,000 cubic feet. When the pond is $2\frac{1}{4}$ feet below its full water-line this fish-way is inoperative.

Judging from the amount of rain which fell at the other places mentioned in the table, we are of the opinion that the annual rainfall on the upper part and on the greater part of the Mystic basin could not have averaged less than 30 inches for the years 1870 and 1871.

In English practice the amount of the annual rain lost by absorption and evaporation is looked upon as nearly a fixed quantity, amounting to from 10 to 12 inches on ground with steep slopes, and from 14 to 18 inches on ground with easy

slopes; the remainder is considered collectable. If we allowed 15 inches in this case there would remain by this rule 15 inches flowing off and capable of being utilized by storage or otherwise. But the English rule has failed in very dry seasons, as at Liverpool, Leicester, and Dublin. It is not necessary to argue how far nor how applicable it may be made to our climate; the experience on the Cochituate basin being on the whole a safer guide in this respect than the other. The flow of that basin has been calculated for the years 1862 to 1871. The percentage of the year's rainfall that reached the lake was least in 1866 (26 per cent.), but the water flowing off at the Cochituate gate-house by its equivalent in inches of the rain falling on the basin was least in 1871, when it was equivalent to 14.68 inches; in 1866 it was 16.01. In the report of Messrs. John B. Jervis and W. R. Johnson, of November 18th, 1845, they state as the result of observations connected with the New York State Canals, "that experiments have been made in this country that show that from one-third to one-half of the annual fall of rain may be collected into a reservoir." Experience since that date has not altered this general view, although it has enabled us, when precise experiments have been made on the flow of streams, to obtain for particular localities a safer guide than any general law can give.

From the same report the following statements would go to show that the equivalent of water collected from the Long pond or Cochituate basin in 1871 (14.68 inches) is not lower than what might have been anticipated of a very dry season. Messrs. Jervis and Johnson state, "that a gauge of the quantity of water which passed the outlet of this pond was made by them (the Commissioners of 1844) in 1837 and 1838. By this gauge the average daily flow from July 27th, 1837, to July 27, 1838, was (15.36 feet per second), say, 9,927,000 gallons per day; and computing the gauge from November, 1837, to November, 1838, the daily average flow was (21.82 feet per second), say, 14,100,000 gallons per

day. The survey of the country draining into the pond shows an area of 12,077 acres, including the pond. The quantity found by the Commissioners for the year commencing July 27th, 1837, was 15.36 cubic feet per second. This is equal to 0.975 of a foot, or 11.70 inches in depth that must have been collected from the whole area of drainage. The rain that fell at Boston during the same time was, according to Dr. Hale, 26.65 inches. The ratio of drainage was thereupon 0.439 of the total fall of rain at Boston.

"Taking the Commissioners' gauge at the outlet, for the year commencing Nov., 1837, the discharge averaged 21.82 feet per second. This is equal to 1.385 feet or 16.62 inches in depth collected from the country draining into the pond. The rain that fell during this time at Boston was, according to Dr. Hale, 38.11 inches. The ratio of drainage was therefore 0.436 of the fall of rain in Boston."

"In view of all the facts above presented there appears no reasonable ground to doubt that 0.4 of the fall of rain may be realized as the ratio of the total fall which may be collected from the district that drains into Long pond."

The geological character of the Mystic basin is essentially the same as that of the Cochituate basin; the rocks are of the same general character, and the same may be said of the gravelly or stony earths covering them.

We shall therefore assume in this connection that an equivalent of 15 inches of water may flow off from it during the driest year.

The drainage area of the basin is computed to include 26.04 square miles; deduct for water area of Mystic lake and of the ponds and proposed reservoirs 1.53, and there remains 24½ square miles as the area of its water-shed. Fifteen inches of water from 24.5 square miles is equal to 853,776,000 cubic feet annually.

This amount, if the surplus of its storm waters could be stored and meted out as needed, would be equal to a daily supply of 2,339,112 cubic feet, or 17,497,765 gallons.

The amount of storage desirable to apply usefully the whole of this amount of water is luckily obtainable in this basin, although its available valleys are shallow, and in this respect objectionable for such a purpose. The examination and surveys made within the last two months to that end show that the following storage reservoirs admit of being constructed here. Their positions and relative water areas will be best understood by reference to the accompanying map.

Where the low grounds within these reservoirs are swampy, the muck, brush, and other objectionable matter is supposed to be removed, in order to secure a colorless and acceptable water, and where the natural ground would give large areas of shallow water the reservoir is supposed to be deepened on the channel lines, and the excavation used to raise the shallowest spots above high-water mark.

All this we consider necessary to secure for the water as far as practicable immunity from the taint which sometimes, though rarely, characterizes the shallow waters of our artificial basins during the summer months.

Available storage basins on the Mystic valley, with their respective water areas.

NAME ON MAP.	Water Area.	Available Capacity.
	Acres.	*Cubic feet.*
No. 1. Storage Basin on West Branch	43	16,711,200
" 2. " " " " "	112	48,732,620
" 3. Horn Pond raised	103	8,000,000
" 4. Storage Basin on East Branch	350	151,006,000
" 5. Winchester Basin	100	34,763,000
" 6. Upper Basin on East Branch	30	13,369,000
" 7. Upper Mystic Lakes	230	44,987,000
Total Storage = (2,375,418,000 gallons)		317,568,820

Say 300,000,000 cubic feet, allowing for those portions of the bottom waters which cannot or should not be drawn off.

Reservoir No. 4 supposes the Lowell Railroad, which runs alongside of it, raised 5 feet. If this is not done its storage would be reduced by 62,768,000 cubic feet.

If the restrictions preventing the use of the lower Mystic pond could be removed, the erection of a dam at the lower end would create a storage capacity there of about 40,000,000 cubic feet, provided that the water there could be divested of all trace of the salt water which enters it now, and if it mixes with the fresh water must render it unfit for city use.

The application of this lower pond would give in that case its amount of storage at a less cost, we believe, than an equivalent storage reservoir situated up the valley.

The storage reservoirs, above enumerated, have, then, an aggregate capacity of 300,000,000 cubic feet. This will be a little more than sufficient to insure a daily supply of nearly 17,000,000 gallons during the season of drought which we have been considering.

The following table will explain the action of this amount of storage, and show its aid and effect under this rate of daily consumption. The case is a suppositious one so far as the rainfall applicable to each month is concerned, but the amount of rain flowing off for each month during the year of greatest drought recorded of the Croton basin, and the same for the lowest year of the Cochituate basin, is placed alongside of the amounts assumed for the Mystic basin, for the sake of comparison, as well as to show that our assumptions have a fair measure of probability.

It is always to be remembered that our consideration of the water which can be utilized from this basin regularly through each year, and without fail, refers necessarily to a year of drought.

Effect of the available storage of the Mystic basin; the water utilized taken at 17,000,000 gallons daily, = 2,272,569 *cubic feet.*

Month.	Water flowing off. Croton Basin in 1864.	Coch'te Basin in 1871.	Mystic Basin in year of drought, assumed.	Amount of Rainfall collected for the month.	Amount applied to use.	Amount applied to storage.	Amount drawn from storage.	Amount of Water in store. Total storage capacity, 300,000,000 cubic ft.
	Inches.	*Inches.*	*Inches.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.* 120,000,000.
Jan. .	2.270	1.03	1.70	96,761,280.	70,449,648.	26,311,632.	. . . . . .	146,311,632.
Feb. .	0.874	2.28	2.10	119,528,640.	63,631,948.	55,896,692.	. . . . . .	202,208,324.
March	1.519	2.29	2.00	113,836,800.	70,449,648.	43,387,152.	. . . . . .	245,595,476.
April .	1.626	1.31	1.50	85,377,600.	68,177,079.	17,200,521.	. . . . . .	262,795,997.
May .	2.080	1.47	1.40	79,685,700.	70,449,648.	9,236,052.	. . . . . .	272,032,049.
June .	0.634	0.54	0.50	28,459,200.	68,177,079.	. . . . . .	39,717,879.	232,314,170.
July .	0.201	0.48	0.30	17,075,520.	70,449,648.	. . . . . .	53,374,128.	178,940,042.
Aug. .	0.577	0.90	0.50	28,459,200.	70,449,648.	. . . . . .	41,990,448.	136,949,594.
Sept. .	0.475	0.57	0.60	34,151,040.	68,177,079.	. . . . . .	34,026,039.	102,923,555.
Oct. .	0.940	0.97	1.00	56,918,400.	70,449,648.	. . . . . .	13,531,248.	89,392,307.
Nov. .	1.901	1.61	1.80	102,453,120.	68,177,080.	34,276,040.	. . . . . .	123,668,347.
Dec. .	1.795	1.23	1.60	91,069,440.	70,449,648.	20,619,792.	. . . . . .	144,288,139.
	14.892	14.68	15.00					

From this amount there must be deducted what has been used or lost at the fishway, occupying one of the six spaces on the Mystic dam. This fishway was passing off on the 25th of November last, when we gauged it, about its average quantity, according to Mr. Symmes, the person in charge of the works there. During the four months, April to July, it passes more, lessening during the other months. When the level of the lake is drawn down below a certain line, it ceases to flow. From our gauging and Mr. Symmes' explanations, we make the following estimates of the amount wasted here per year.

In 1870 (86 days not running,)	398,945,000 gallons.	
" 1871 (68 days not running,)	420,480,000 "	
" 1872 (running all the year,)	501,875,000 "	
" 1873 (100 days not running,) . . .	371,935,000 "	
	1,693,235,000	
Average loss per year equal in gallons,	423,308,750	= 56,600,000 cubic feet.
This would make the amount in store at the end of the season		= 87,688,139 cubic feet.

It seems hardly necessary to observe that while these reservoirs can be filled and applied by an intelligent attention to their special conditions, they cannot be used throughout the year pro rata of their capacities; but while from some, where the storage area is in excess of the available capacity, there would be drawn regularly much more than the capacity would indicate, from others, differently situated, an opposite course would have to be followed.

It will be perceived from this table, that but for the fishway, the amount in store at the end of such a season would have been greater than at the beginning of the season, allowing in that case of a yearly consumption averaging $17\frac{1}{2}$ millions gallons, but the action of the fishway makes the amount in store at the end of the season less than at the beginning by 32,311,861 cubic feet, reducing the daily average which can be relied on to about $16\frac{1}{3}$ millions gallons.

To counteract this reduction, however, it will be observed that while the water stored never exceeded 272,000,000 cubic feet, in round numbers, the storage capacities are equal to 300,000,000, and under this condition of things, a certain portion of the water of the previous year could be accommodated, if that year happened to exceed in its water flow the year we have been considering. If the lower Mystic lake could be made available, it would still further insure the help of a previous year toward what could be gathered in a year of severe drought, and perhaps raise the available yearly average to 18,000,000 gallons.

It must, however, be kept in view, that the great irregularity in the relative amounts of rain falling monthly makes necessary a liberal margin to the amount of provision which would be sufficient for years of average regularity in that respect. The table supposes 120,000,000 cubic feet in store on the 1st of January, because that must include the months of November and December of the previous year,

and that reserve of at least one month's supply, which is never supposed to be encroached upon.

Referring now to the table formerly given, showing the estimated condition of the population, and its consumption of water to 1910, we see that if we rate the consumption at 60 gallons per head per day, the rate of 17,000,000 gallons a day would be reached in 1901, and if we take it at 70 gallons a head, it would be reached in 1898.

Stated more succinctly, the waters of the Mystic valley basin, well economized, by proper storage, will probably suffice for the need of the district now depending on it, up to 1900, but not beyond that period.

If a portion of this population should hereafter be provided with water from other sources, it would to that extent modify the calculation.

Under the circumstances which now obtain, it is evident that Boston cannot depend on the waters of the Mystic valley for any permanent addition to her present supply; but an important temporary addition to her present supply may be obtained here.

This could not be got, however, without the aid of storage reservoirs, and it would take two seasons diligently employed to construct these.

By this means there might be applied in 1876 seven or eight millions gallons towards the supply of the city proper, and seven millions at least of this amount could be continued to 1880, when, if the works contemplated elsewhere are completed, it would be no longer needed. After 1882 the amount might begin to be encroached upon by the requirements of the district now using this water.

The estimated costs of the storage basins required to apply the waters of the Mystic basin are as follows: —

Storage basin No. 1	$90,976 00
" " No. 2	167,966 00
" " No. 3, being the application of Horn Pond to secure the drainage waters below Nos. 1 and 2, and within the control of Horn Pond	8,500 00
" basin No. 4	642,120 00
" " No. 5, constructed by Winchester Water Works	0 00
" basin No. 6	85,000 00
	$994,562 00

The construction first of No. 2 and No. 4, with a joint capacity of 199,738,620 cubic feet, say 200,000,000 cubic feet, would admit of the application of 5,000,000 gallons per diem to begin with, and as this amount, with the aid of Cambridge, may be sufficient to meet the requirements of the city until the Sudbury works are available, we shall first give an approximate estimate of the cost attending the introduction of this quantity: —

Cost of Storage basin No. 2		$167,966 00
" " " No. 4		642,120 00
Pumping engines and engine-house at Charlestown, delivering into the Charlestown reservoir:		
Foundations of engines, engine-house, boiler-house and chimney .	$45,000	
Engine-house, boiler-house and chimney	40,000	
Amounts carried forward,	$85,000	$810,086 00

Amounts brought forward, .	$85,000	$810,086 00
Two pumping-engines, each with capacity to deliver 5,000,000 gallons in 24 hours	150,000	
		235,000 00
3,300 cubic feet of 30-inch force main . .		37,000 00
Pipe connecting the reservoir with the existing distribution-pipe of Boston, 20,520 feet of 30-inch pipe		215,460 00
1,440 feet of patent ball and socket 30-inch pipe across Charles River, including dredging		84,000 00
Check-valve and stop-cocks		12,000 00
Work connecting with the reservoir . .		15,000 00
		$1,408,546 00

The lift at Charlestown, including the friction of the pipe, may be taken at 153 feet.

The cost of delivering 1,000,000 gallons 100 feet high, including fuel, oil, etc., attendance and ordinary repairs, is found to average, for good engines, about $12.00; equal for 153 feet to $18.36 per million gallons.

This, for 5,000,000 gallons, would give an expenditure of $91.80 per diem.

To deliver 5,000,000 gallons daily from the Mystic basin would thus involve an expenditure of say $1,400,000, and the cost of pumping this amount into the Charlestown reservoir would be about $92.00 daily.

It is to be noted that this expenditure for reservoirs and pumping-engines would not be thrown away, after the city of Boston ceased to require the water, inasmuch as such storage reservoirs and power will be needed for the population of the valley, but much of this outlay would be for a while in advance of the needs of that population.

The cost of this water to the city, allowing 7 per cent. for

the capital invested, and including the expenses at the engine-house, would be $7\frac{1}{4}$ cents per thousand gallons; including superintendence at the reservoirs and repairs, it might reach 8 cents per thousand gallons, delivered; a rate which for such special service cannot be deemed unreasonable.

Having endeavored to understand the condition and resources of the Mystic valley as regards quantity of water, we come now to its condition as regards purity.

The natural waters of the Mystic valley are, as might be expected from the geological features of the basin, very pure and colorless; but the tanneries and other manufactories situated at and in the neighborhood of Woburn affect more or less the color of the main stream, and measurably its purity. When we visited the ground, the water of Russell's brook, which receives the refuse of ten of the tanneries, was exceedingly nauseous to the smell and taste.

The report of Professor Horsford will give the chemical properties minutely of the Mystic waters. We will mention here, however, the principal prejudicial influences to which it is subject.

These are the different manufactories referred to, and the sewerage of the towns of Woburn and Winchester.

The sewerage of these thriving places has not yet taken a concentrated shape, but, with the introduction of water, this will speedily follow. If this sewerage is intercepted and delivered into the river below the Mystic lakes, it will relieve the stream from so much pollution, but as the cost of effecting this would be considerable, it is not likely to be carried out very soon.

The manufactories alluded to number as follows: —

Tanneries	20
Wool-scouring Establishments . .	1
Morocco Factory	1
Glue Factories	2

Chemical Works	1
Pig-Slaughtering House . . .	1
Piggery (200 heads)	1
	27

The tanneries cure, on an average, 1,200 hides and 525 calf or alligator skins daily, — say equal to 1,300 hides daily. Each hide is variously estimated to use from 450 to 200 gallons of water during the process of curing. Take the lowest figure, and it gives 260,000 gallons of very impure water passing into the river daily. If it is considered that during a season of very low water, the river, judging from the area of its basin, may be flowing then less than 4,000,000 gallons daily, the introduction of this amount of very objectionable water could hardly fail to be perceptible between Russell's brook and the Mystic lake. Its passage, however, through the large body of water in the upper Mystic pond, admits of such a diffusion as to render such impurities entirely imperceptible to our senses at the lower end of the pond, where the Charlestown works have their conduit connection. When the river is in flood the relative proportions of pure and impure water would be entirely changed, obliterating, for the time, all trace of the latter.

Notwithstanding all this, the impurity is of a character that it is very desirable to be rid of it; and it is growing continually with the growth of Woburn, Winchester and their neighborhood.

We have had estimates made accordingly for a sewer sufficiently large to receive the refuse waters of all these establishments and convey them to tide-water. This would require 8.68 miles of sewers of various diameters at an aggregate cost of $264,000.

To purify the refuse waters from tanneries, irrigation has been tried, but, so far as we can ascertain, unsuccessfully both here and in England. Mixed with sewage, it is supposed

that it might be made available in this way where the circumstances otherwise admitted of such an application economically. We cannot learn that any process has been used to destroy the impure elements in the refuse water of tanneries, although such a process is hinted at in one of the English reports on the pollution of rivers.

Your instructions require of us an expression of opinion in regard to "the changes needed to prevent any waste of the present supply."

The average daily consumption of water in the city for the years 1869 to 1872 show that much has been already done towards the reduction of this evil, since the natural increase in the consumption due to the growth of the population and its business does not appear here.

The rate per diem is reported as follows: —

1869	15,070,400
1870	15,007,700
1871	13,945,500
1872	15,063,400
1873	17,896,000

There are here four years when the consumption of water did not increase; in 1871 it was, in fact, reduced by a little over 1,000,000 gallons per diem, and in 1872 would probably have stood below the consumption of 1869, had not the great fire occurred to increase somewhat its natural proportion. In 1873 the rate of consumption rises again, showing either that the waste had been finally subdued as far as the officials had power to subdue it, or that their efforts that way had been to some extent interrupted.

The waste of water may be referred to three general heads: —

1. Leakage in the street pipes and mains.

2. Leakage within the houses from imperfect or improper fittings.

3. Waste within the houses during the winter months from allowing water to run off during the night to prevent freezing of the pipes.

The first cause of waste can never be entirely corrected, but it is being continually reduced as such leaks become known, either by their exhibition in the sewers or otherwise.

Towards the correction of the second cause there should exist a discreet but efficient water police, having the right, at reasonable hours, to examine all the fittings, systematically, of all the premises in the city, and to advise, as well as report, when these are defective. To render such action efficient, the Water Board must have power, where due notice or advice is not respected, to cut off the water until the proper correction is made. They should, in other words, have ample power to correct the causes of waste wherever they appear, and to take such steps as the circumstances require to ascertain them.

The third cause — of waste growing out of our severe winters and the bursting of service-pipes by frost — is not so easily dealt with. Until the service-pipe can be efficiently protected from this contingency, the servants of any house can hardly be condemned for taking the only measures they know of to avoid it. The Board, after showing how this protection can be given, should have power to insist upon its application, and to charge for its non-application according to the amount of water they judge to be wasted.

We see no means, then, of reducing the waste to its narrowest limits, for it can never be entirely suppressed, except by investing those in charge of the water supply with ample powers towards that end, — such powers as, in their experience, they may find to be necessary in addition to those already possessed by them. As it is an exceedingly delicate and thankless task to carry out the measures necessary to correct the losses alluded to, the officers in charge will, we

should think, be more likely to use their powers moderately than to exceed them.

CONDUIT OF COCHITUATE WATER WORKS.

An examination of the interior of the brick conduit was made November 19th and 20th last, by persons who walked through its whole length, a report of which is annexed.

Some parts were found to be in very dangerous condition.

The conduit is built of a single thickness (eight inches) of brick, supported on the bottom and sides by earth, which appears to have yielded in many places, causing numerous cracks in the brick-work, generally at the top and bottom of the conduit.

By reference to the annual reports of the Cochituate Water Board and accompanying documents, we find that fine cracks of the same character "were discovered before and about the time the aqueduct was completed."

Within a few years after the water was admitted, repairs were made by pointing up the cracks, and in some cases cutting out brick-work and relaying it.

The cracks have continued to reopen, or others to appear, making frequent repairs necessary.

This operation, repeated at the same place, has resulted in considerable changes in the original form, reducing the height and increasing the width. Measurements made during the recent examination show an increase of width in many places of from one to three inches, and in one place of nearly six inches, and a diminution in the height, but of less amount.

We find, from the same reports, that the depth of water in the conduit was not originally expected to exceed about four feet, or about two-thirds of the height of the conduit, but the demands for water have made it necessary to run a great part of it nearly or quite full for many years, and frequently under a head of several inches in addition. The greater pressure

resulting from this use has undoubtedly increased materially the trouble, but the fact mentioned above, that cracks began to appear before any water was admitted, indicates that they are not wholly due to the pressure of the water.

The demands of the city for water have been such that the flow through the conduit could be interrupted only for short periods, which must frequently have prevented the repairs being made in the thorough manner they would otherwise have been.

This opening of cracks in the brick-work and imperfect repairs, frequently repeated at the same places, during the last twenty years, must have deteriorated the work and rendered it more liable to rupture from the excessive pressure to which it is now exposed.

The recent examination has shown, very clearly, that parts of the conduit are now unsafe, and may fail at any time. With the increasing population to be supplied, the demands for water must also increase, which, until other sources of supply are provided, will be likely to lead to forcing more water through the conduit, and increase the liability to breaks.

We are of opinion that arrangements should be made, as soon as practicable, for the thorough repair of the parts of the conduit that are in a dangerous condition, and also to limit the quantity of water passing through it to about seventeen millions of gallons per day, which we think is all that it will carry without having a head on some parts of the line. With the increasing population, this will require either increased economy in the use of the water or an immediate additional supply from some other source.

FLAX POND.

In your communication of the 25th Nov. last, you state that it is the desire of the Water Board that, in connection with our report upon the Mystic basin as a source of supply for Boston, we should also consider and report upon the Flax

pond basin in Lynn; whether in our opinion "the quantity of water to be derived from the latter would warrant the expense of connecting it with Mystic lake, or the pump well, making it supplementary to the Mystic supply."

An examination of this pond, together with Sluice and Cedar ponds, its tributaries, was made by Mr. William J. McAlpine, as sources of supply to the city of Lynn, the results of which are contained in his report to the authorities of Lynn, dated August 1st, 1870.

From this report we gather that the water-shed is 2.48 square miles, which can be extended by catch-water drains to about three square miles; and by using the three ponds to the depth of eight feet as storage reservoirs, it was estimated they would furnish an average daily supply of three million gallons.

Mr. George R. Baldwin, in 1850, examined Sluice pond as a source of supply to the city of Salem; and from a copy of his report shown us, we gather that, relying on a water-shed of 4,200 acres, or 6.56 square miles, "judging of its capacity by the topography of the plan of Lynn," he estimated that it would furnish an average daily supply of 5,356,000 gallons.

We have had no opportunity of verifying either of these estimates by actual surveys, but it is obvious that Mr. McAlpine had much the best means of estimating the supply, the water-shed having been minutely surveyed for the purpose; and we are of opinion that his estimate of an average daily supply of three million gallons is fully as large as the circumstances warrant, and that in a dry year it will probably fall considerably below that quantity.

In order to deliver the water gathered from the water-shed, as a uniform daily supply, it is necessary, as Mr. McAlpine contemplated, to provide a large amount of storage. Sluice and Cedar ponds, as we are informed, can easily be converted into storage reservoirs. Flax pond near its

outlet, is within the populated part of Lynn, and we are informed, building is rapidly extending round its margin. The level of the ground for a considerable distance near the outlet is but a few feet above the usual height of the water, and if its level is raised materially, a dike of considerable length must be built on the margin. Raising the level of the water above the level of the ground, on which houses in the vicinity are already built, will undoubtedly be considered an injury to the value of the property, and possibly to health. We think it would be less objectionable, to get the required storage in this pond by drawing it below its usual height. The ground near the outlet will allow the effluent pipe to be laid low enough to permit the water to flow out, by gravity, to the required depth. When the pond is drawn down, a certain area of flats will be laid bare, which in the hot weather we think may be offensive to the neighborhood, and perhaps be deemed injurious to health. This objection applies also to the plan of raising the level of the pond.

Between Sluice and Flax ponds there is a dam and mill, now used for pulling wool and tanning sheep-skins, and a large amount of polluted water passes from these works into Flax pond, which it would be necessary to discontinue. The natural drainage from the houses, etc., on the margin of Flax pond, is into the pond. If the water is to be used for domestic purposes, a system of sewerage must be provided to divert it.

The cost of conveying the water of Flax pond to the pump-well of the Charlestown works, a distance of eleven and a quarter miles, together with the additional cost of pumping engines and mains to deliver the water in Boston, is estimated at $1,327,847, which, in addition to the cost of the works, is intended to cover the probable amount of damages to be paid for diverting the water and otherwise, which is necessarily very uncertain.

On account of the great cost for the quantity of water to

be obtained, together with the probability that the use of Flax pond as a storage reservoir may be objected to on the ground of its effect on health, we are of opinion that it would not be advisable to connect it with Mystic lake or the pump-well as a supplementary source of supply for Boston.

It may be well to recapitulate here the results of our examinations on the points referred to us.

First.—Quantity. The quantity of water which can be relied on from the "Mystic pond," by which we mean the Mystic valley, during a season of drought, and with the aid of storage reservoirs, will not, in our opinion, exceed a daily average of seventeen millions gallons, unless the lower Mystic pond is utilized, when it might probably reach an average of eighteen millions gallons daily.

The population now depending on this water will, it is calculated, number 269,000 souls in 1900, and will by 1898 or 1899 require all the water that the valley can furnish during a year of drought. The City of Boston cannot, therefore, rely on this basin as a source of supply, except temporarily. Until 1880 there can be drawn from this valley by means of the construction of two of the indicated storage reservoirs, a supplementary supply of 5,000,000 gallons daily, at a cost delivered, as we estimate it, of eight cents per 1,000 gallons.

By constructing all the storage reservoirs mentioned in this report, the amount might be increased to seven or eight millions gallons daily; but we have not carried out this estimate, assuming that the supply of 5,000,000 gallons daily might perhaps meet the immediate necessities of the case with the aid of what can be got from the Cambridge Water works, and that the other storage reservoirs could be added from time to time as they may be needed. It is to be noted that the Charlestown Works will feel the need of a storage reservoir, in all probability, before either of the two above alluded to can be constructed; this has been foreseen, and

their capacities will meet, as well the varying requirements of the Charlestown works.

Second. — Purity. The Mystic river, before it enters the Mystic pond receives the refuse waters of certain tanneries and glue factories, elsewhere enumerated, which, judging by their effect on the Russell's brook, — one of its lesser tributaries, — are of a very impure and objectionable character.

The river may be further contaminated, by and by, by the sewage from the towns of Woburn and Winchester, when the construction of sewerage works at these places shall collect and concentrate it. Both of these descriptions of impurity are very objectionable contributions to a river water, but we do not think that they are likely to be for some time perceptible, after passing through the deep waters of the Mystic pond, nor that they are sufficient to render the water drawn from that pond for Charlestown and other places, in any sense, unfit now for domestic use.

They can all be intercepted and carried to tide-water whenever, either from their increased quantity or a greater sensitiveness on the part of the water consumers, this course may become desirable.

Third. — The Cochituate Conduit. This conduit is overtaxed now, and shows in many places signs of weakness and yielding, the most dangerous of which should, we think, be repaired and made safe next spring. The conduit cannot be thoroughly overhauled and repaired until an independent supply of water is available for the city from other sources, sufficient to admit of the Cochituate conduit being relieved from duty for some months. Until such an opportunity can be had, we are of opinion that it should not, in its present condition, be relied on to convey more than 17,000,000 gallons in any one day.

Fourth. — Waste of water. To reduce this waste to its minimum and hold it in check, greater power, in our opinion, should be conferred on the Water Board, to enable them

to require the correction, under penalties, of insufficient fittings within the premises of water-takers; to ascertain by frequent examination where these exist, and to prescribe the classes of service-pipes, and all kinds of fittings which are best calculated to defend the city against that needless waste which is known to exist, and which seems to be less under check here, than in any other of our large cities.

Fifth. — *Flax pond.* The addition of the water of Flax pond to your supply appears to us inadvisable, both on account of its relative cost, and of the difficulties which would probably arise in its application.

Which is respectfully submitted.

JAMES P. KIRKWOOD,
JAMES B. FRANCIS.

APPENDIX.

APPENDIX.

BOSTON, November 20th, 1873.

JAMES P. KIRKWOOD, Esq.,
JAMES B. FRANCIS, Esq.,

Gentlemen,—According to directions received I have just made an examination of the Cochituate Conduit by walking through from the lake to the Chestnut Hill Reservoir, in company with Mr. Joseph Wiggin, Clerk of the Water Board, and Mr. D. Fitz Gerald, Superintendent of the Western Division; and have to report as follows: —

November 19. Entered the Conduit at Lake Cochituate at 9 A. M.

Station 12. From lake to this point considerable vegetable growth of a substance resembling sponge and a sort of black moss.

Station 13. Sides well covered with black moss.

Station 17½. Bottom apparently three inches below grade for about 25 feet.

Station 26. Bottom appears to be about three inches above grade for a short distance. Measure 6.28 x 5. 1.*

Station 122. Water springs in at bottom bringing fine sand.

141 to 142½, near Stevens' brook. Crack in top ⅛ to ¼ inch wide, probably new, sand in bottom. Size 6.3 x 5.13.

152 to 153. Slight crack in top.

154 to 155.20. Cracks in top and bottom. Size 6.33 x 5.13.

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* The size of the conduit as built, is, height 6.33 ft. width 5 feet.

Dedman's Brook.

Arrived 11.45; came out; 1 P. M. re-entered.

156 to 158.50. Slight crack in top, an old one, no change Size 6.3 x 5.04.

Station 167.50. Crack in top ¼ inch wide and about ten feet long. An old one. Size 6.4 x 5.17.

Station 178 to 181. Paddock's Pond. Old crack in top about ⅛ inch wide.

Station 207 to 208.20. Slight crack in top. Size 6.3 x 5.12.

245 to 246. Old crack in top ⅛ inch wide. Size 6.3 x 5.17.

248½ to 249. Old crack in top, no change. Size 6.3 x by 5.12.

252.50. Slight crack on top.

253 to 254. Embankment. Quantities of roots, some as large as my little finger, growing into and apparently through joints, also a small crack on top.

254. Size 6.25 x 5.22.

255 to 256. Embankment, wide crack in top and bottom.

262½ to 264. Slight crack in top. Size 6.28 x 5.27.

272 to 274½. Embankment, old crack in top, quite wide, appears not to have started since last year. Size 6.26 x 5.13.

283½ to 284. Slight crack in top, an old one.

284½ to 285½. Slight crack in top, left hand. Size 6.24 x 5.12.

300. Measures 6.16 x 5.13. *End of Division 1.*

Division No. 2.

Station 13 to 14. Old crack in top, pointed and cracked again. Size 6.14 x 5.21.

13½. Large spring of water in bottom.

15½ to 17. Old crack in top, quite wide, pointed and started again. Size 6.12 x 5.17.

17 to 18. Old crack in top quite large, has been pointed and started again; water springs in at bottom, size 6.11 x 5.15.

Station 30½. Mud and roots in bottom.

Station 49½. *Grantville Waste Wier* arrived at 4.10 P.M., left at 4.15.

52 to 54½. Slight crack in top.

63½ to 64½. Slight crack in top, size 6.3 x 5.05.

77 to 78. Several cracks.

107 to 109½. *Lower Falls, high embankment:* Bad cracks along top and bottom; very wide in many places; have been pointed and started again; conduit badly out of shape, a probe was pushed through bottom crack and two feet into the gravel below; size 6.18 x 5.30.

108. Worst place, wide cracks top and bottom; is in a very dangerous condition, size 6.0 x 5.48.

111½. Pipe chamber, Newton Lower Falls, arrived at 5¼ P.M.

Charles River Crossing.

November 20. Re-entered at East Pipe Chamber 10.20 A.M., about Station 122.

Station 160. Crack in top 50 feet long, both sides of a man-hole.

169¼ to 170. Slight crack in top, size 6.37 x 5.08.

178½ to 179. Slight crack in top; roots growing into sides; size 6.33 x 5.07.

195½ to 196½. Slight crack in top, size 6.35 x 5.03.

216¼ to 218¼. Several bad cracks in different joints, left hand, top and bottom, ⅛ to ¼ inch wide, size 6.31 x 5.06; at 218, size 6.28 x 5.06.

223½ to 224. Slight crack in top.

224 to 225. Several large cracks in top, left hand, and one in bottom, probably new ones; size 6.26 x 5.13.

$226\frac{3}{4}$ to $228\frac{1}{2}$. Slight cracks in top.

$232\frac{1}{2}$ to $238\frac{1}{2}$. Bad cracks top and bottom, $\frac{1}{4}$ inch wide, and a crack in bottom on south side, size 6.28 x 5.14.

242.60 to 244. Near a man-hole and in embankment; two of the worst cracks we have seen in the top, and also two bad ones in bottom, $\frac{1}{4}$ to $\frac{1}{2}$ inch wide, large roots growing in at top; size 6.21 x 5.21.

$247\frac{1}{2}$ to 248. Very slight cracks in top.

$253\frac{1}{2}$ to $254\frac{1}{2}$. Slight crack in top, size 6.30 x 5.15.

$263\frac{1}{2}$ to $264\frac{1}{4}$. Cracks in top and bottom, size 6.27 x 5.11.

DIVISION No. 3.

1 to $2\frac{1}{2}$. Slight crack in top, size 6.29 x 5.06.

$6\frac{3}{4}$ to 7. Small crack in top.

Station 9. Waste-Weir Newton Centre, arrived at 1 o'clock 5 minutes.

$11\frac{1}{2}$ to $12\frac{1}{2}$. Very slight crack in top.

$19\frac{1}{2}$ to 20. " " " "

21 to $21\frac{1}{4}$. " " " "

22. Size 6.26 x 5.13.

$33\frac{1}{2}$. Old brick and cement dam 5 or 6 inches high.

$35\frac{1}{2}$. Another dam and rubbish in bottom.

$37\frac{1}{2}$. Copious spring in bottom, smells of sulphur.

39. Roots and springs.

$50\frac{1}{2}$ to $52\frac{1}{2}$. Cracks in top and bottom $\frac{1}{8}$ to $\frac{1}{4}$ inch wide.

51. Hole in bottom, spring of water.

$51\frac{1}{2}$. Size 6.20 x 5.10.

52. Crack in bottom, on right, size 6.25x5.20.

Newton Tunnel,

West End, nine inches of mud, and through whole length from three to six inches of mud.

Ventilator; arrived at 2.10, left at 2.30.

$86\frac{1}{2}$ to $87\frac{1}{2}$. Quite a crack on right near top; also one in bottom.

89 to 89.30. Crack in middle, top, and bottom.

90 to $90\frac{1}{2}$. Crack $\frac{1}{8}$ to $\frac{1}{4}$ inch right side, size 6.4 x 5.12.

94. Slight crack, right, near top.

$107\frac{1}{2}$ to 108. Slight crack in top.

109 to 110. Two cracks at right of top $\frac{1}{8}$ inch, size 6.31 x 5.05.

$115\frac{1}{2}$ to $116\frac{3}{4}$. Slight crack in top.

$117\frac{3}{4}$ to $118\frac{1}{2}$. Two slight cracks in top.

$118\frac{3}{4}$ to $119\frac{1}{4}$. Slight crack in top.

$119\frac{1}{2}$ to 124. Bad cracks, top and bottom, $\frac{1}{4}$ inch and over.

121. Size 6.20 x 5.27.

122. Size 6.24 x 5.22; all along this portion bottom is rough, remains of old cement dams.

125. Old crack, has been pointed, not visibly started.

$125\frac{1}{2}$ to 126. Small crack top, size 6.3 x 5.15.

127. Small crack in top.

Chestnut Hill Reservoir, just above intermediate Gate Chamber, new conduit, cement-lined all through, has a slight crack along the top.

Finished examinations at 4 P.M.

Respectfully submitted,

DAVID W. CUNNINGHAM,

First Assistant Engineer — New Supply.

REPORT

OF

PROF. E. N. HORSFORD,

UPON THE

PURITY OF THE MYSTIC WATER.

1873.

REPORT ON THE PURITY OF THE MYSTIC WATER.

JOHN A. HAVEN, ESQ.,

President of the Cochituate Water Board:—

SIR, — At the request of your Board I undertook, about the 1st of November last, the examination of the waters of the basin of the Upper Mystic, with a view to determining the present and prospective fitness of the Mystic Pond water for domestic use.

Previous labors had made me somewhat familiar with the region, but it seemed desirable to examine the ground anew, and with your Superintendent, Mr. Stanwood, I made at once a comprehensive survey of the streams and ponds, and the factories embraced in the water-shed; and soon after caused to be collected such samples of water and deposits as promised to enable chemistry to answer the questions propounded. These waters and deposits have been analyzed, and I respectfully submit the results of analysis and the inferences that seem to flow from them.

The present salubrity of the water of the Upper Mystic may be accepted as having been settled by the experience of the cities which have used it for some seven years. If there be any doubt upon this point, the following analyses will serve to give to the distrust the measure of consideration to which it is fairly entitled.

There was contained in one gallon

			Inorganic.	Organic.	Total.
Of Croton,	in	1845,	6.66	4.28	10.93
" Fresh pond,	"	1873,	5.67	2.36	8.03
" Mystic,	"	1873,	3.78	2.83	6.61
" Cochituate,	"	1873,	3.12	1.24	4.36

The *prospective* fitness, for domestic use, of the water of the Upper Mystic pond involves two kinds of considerations.

1st. Is it liable, as some other waters are, to acquire greater or less increase of its inorganic matters? and

2d. Is it liable, for reasons peculiar to itself, to acquire increased proportions of *organic matters* as well as inorganic matters?

The increase of lime and magnesia salts tends to make a water hard. The increase of soda or potash salts produces no harm except the quantity be very great. Increase of organic matter may bring with it objectionable qualities, both for boiler use and in regard to salubrity.

The first analysis of Cochituate water in 1845 gave in one gallon,

Inorganic matter . . .	1.22 grains.
Organic "	0.63 "
Total	1.85 "

An analysis in the course of this investigation, in 1873, gave of

Inorganic matter	3.12 grains.
Organic "	1.24 "
Total	4.36 "

This increase is very considerable, although the water is undoubtedly one of the purest supplied to any large city. Moreover, the past history of the water shows that it is liable to considerable fluctuations.

The first analysis of Fresh pond water, made in 1853, gave per gallon,

Of Inorganic matter . . .	5.01 grains.
" Organic " . . .	1.35 "
Total	6.36 "

It now, Dec. 20, 1873, contains,

Of Inorganic matter . . .	5.67	grains.
" Organic " . . .	2.36	"
Total	8.03	"

The water of the Schuylkill gave,

In 1842		4.10	grains.
" 1845, Inorganic matter . . .	4.26		
Organic " . . .	1.24		
Total	5.50	5.50	"
In 1854		6.11	"

The surface of the Mystic contained,

In 1836,	Total residue per gallon,	1.17	grains.
" 1845,	" " " "	2.33	"
" 1859,	" " " "	4.08	"
" 1860, October,	" " " "	7.67	"
" 1862 (Silliman),	" " " "	9.58	"
" 1872, November,	" " " "	5.30	"
" 1873, November,	" " " "	6.61	"

The occasional increase in the amount of mineral matter in the waters of Lake Cochituate, as compared with that at the time this water was first introduced for the supply of Boston, is an interesting fact.

Possibly the following explanation is adequate in part to account for the oscillation.

When the water of Lake Cochituate was analyzed in 1845, the lake had been standing at, or near, its normal level for ages. The soil, for a considerable distance from its shores, contained in solution the usual constituents of arable soils in primitive regions. Of these, a portion were in solution.

Within certain average limits these constituents remained unchanged, and oscillated between certain higher and lower levels in the soil, under the influence of evaporation on the one hand, and alternating accessions of rain water on the other.

But when occasion required the drawing down of the water considerably below the mean level, the water of the surrounding soil, with whatever it held in solution, naturally flowed into the lake. Every oscillation of level repeated this process.

The wants of the city of Boston have repeatedly provided this occasion for an influx of saline matter into the pond.

The accession of the water of Sudbury river for a time seemed to increase the foreign matter. But I am disposed to look upon the present analysis as giving an exceptional result, and that the substantial purity of the water for all time is assured. A year ago the water was nearly as pure as it was in 1845, as the following figures show: —

Total residue in 1845 . . .	1.85 grains.
" " " 1872 . . .	2.06 "

The present level of Fresh pond is much below — several feet below — its natural outlet, and it seems possible that the same phenomenon as that occurring at Lake Cochituate is being repeated in this sheet of water, with the probability that the water displaced by rainfalls from the surrounding marshes contains more saline matter to be forced into the pond. The stratum of salt water below, brought in by high tides in times long gone by, is doubtless diffusing itself with a relatively increased rapidity as the outflow of surface water over the dam is cut off.

The increase in the amount of inorganic matters in the Schuylkill finds explanation in the increased cultivation of the land on the shores of the tributaries, and in the burning of wood to

ashes in clearing new land from 1842 to 1854, and, perhaps, to the sulphur of the iron pyrites brought to the surface in the coal, and oxidizing spontaneously or burned in the manufacturing industries.

In more recent times, the increase of manufactures in the towns on and near the banks of the river and its tributaries have appreciably lessened the purity of the water. But I have at hand no recent analysis of the water to enable me to judge.

The opinion of Booth and Boye, of Philadelphia, after a careful analysis of the Schuylkill water, following an interval of twelve years, in 1854, is that the development of manufactures on the tributaries to the Schuylkill had not in that time deteriorated the water in the quantity of *organic matter* in the *slightest degree*, though the inorganic matter had been slightly increased. In the judgment of these gentlemen the water had "deteriorated in no important respect from its former excellent quality."

The Croton reservoirs have been recently enormously enlarged, introducing large volumes of water from more interior drainage, so that the comparison of earlier and later analyses has no particular significance in its bearing upon the point in consideration.

The low marginal territory of the Upper Mystic is less extensive than that of Fresh pond, and the occasions of its being drawn down have been fewer. Practically speaking, there is little if any marsh land saturated with sea-water about Mystic pond.

Let us place side by side the analyses of the waters made at or near the time of their introduction for aqueduct use, with those of more recent date: —

		Total to one gallon.		Total to one gallon.	Increase in years.
Schuylkill,	1843,	4.10;	1854,	6.11;	2.00 in 12
Fresh Pond,	1853,	6.36;	1873,	8.03;	1.67 in 20
					Decrease.
Mystic,	1860,	7.67;	1873,	6.61;	1.06 in 13

This exhibit is, at least, not prejudicial to the good repute of the Mystic water. It had, in 1860, of inorganic, 5.46; organic, 2.20; 1870, inorganic, 3.78; organic, 2.83.

What is the real significance of an accession of inorganic salts?

This topic has received a large amount of attention, in England, more especially. It is an interesting fact, the result of experience and observation, that the rates of mortality are not in the proportion of foreign inorganic matters present in town supplies of water, but in the ratio of their *absence*. That is, the nearer a water approaches absolute purity inside a certain normal limit, the *less* suited is it to meet the demands of the ordinary organism.

It used to be believed that a hard water — that is, a water which, on account of its hardness, was less serviceable for laundry purposes — was less healthful. But Dr. Letheby, of London, has made a collection of the death-rates of a large number of towns supplied by aqueducts, and placed these rates in a table side by side with the degrees of hardness of the water (the measures of salts of lime and magnesia) supplied to the several towns, and the result shows that the death-rates rise with the increased purity of the water.

The degrees of hardness in the following table are relative, — based on the curdling produced in the water by the addition of graduated solutions of soap in alcohol: —

Table showing Hardness of the Water Supply and the Death-Rates.

Hardness.	No. of Towns.	Average death-rate per 1,000.	Average hardness.
Over 10°	25	21.9	16.
10° to 6°	17	24.9	8.
6° to 2°	15	26.3	3.8
2° and under	8	28.5	1.3

Now, while it would doubtless be well to act with caution in applying the obvious deduction from this table, it may serve to relieve us of special solicitude in regard to moderate accessions of inorganic matter to the remarkably soft waters of our primitive district.

It may be remarked that the lime salts which make water hard serve in the formation of bones. Wheat, from which most of our bread is produced, contains an abundance of phosphate of potash, but rarely more than a trace of phosphate of lime. The juices of flesh contain large measures of phosphate of potash with relatively little of phosphate of lime. The deficiency in the food is made up in part by the lime derived from the drinking water.

It is obvious upon a glance at the foregoing that, so far as general *natural* agencies are concerned, the future of the upper Mystic pond water may be contemplated without solicitude. There is nothing in the way of organic or inorganic matter likely to be seriously increased from any natural condition of the basin.

There is, however, the second kind of consideration, which grows out of the presence on the tributaries to Mystic pond of numerous manufacturing establishments connected with the treatment of the hides of animals, in the washing, dressing and tanning of which large quantities of water are used, and then turned with more or less of care, or with no care, in regard to settling or purification, into the streams leading to the pond. Besides these there is an establishment for refining glue stock; and a glue factory hitherto in operation in one part of the basin is about to be removed to another. It is in view of these establishments, and the prospective domestic sewage of a growing population, that the future salubrity of the water is thought to be endangered.

The main channels through which the Mystic basin finds its outlet are Cummings' brook, Kendall's brook, Russell's brook, and the lesser tributaries to Horn pond and Wedge

pond on the west, and the Abajonna with its tributaries on the east.

It has been deemed desirable to ascertain what has been, and what is now, the effect of the more important factories upon the excellence of the water. The collections of water have been made at points immediately above and below these works, as well as at points nearer the sources of the trib u taries, and at various depths in the upper Mystic pond. Besides these, numerous deposits from the bottoms of the streams near factories, and at various distances from them, to determine the extent to which the deposits are carried, have been collected, and, with the waters, have been analyzed.

The analytical results are presented in the two following tables : —

TABLE I.

No. of Sample.	Locality.	Deposit.	Color.	Taste.	Smell.	Reaction.	Inorganic Salts.	Organic driven out by heat.	Total.	General Remarks.
No. 0	Drain from Moseley's tannery.	One half the volume a deposit of reddish brown leather powder and carbonate of lime.	Dark red.	Of salt and lea.	Offensive.	Neutral.	252.63	64.10	316.73	Carb. and Nit. in residue from evaporation.
No. 1	Abajonna, immediately above Moseley's tannery.	No deposit.	Colorless and clear.	Tasteless.	Inodorous.	Very faintly acid.	4.70	3.76	8.46	
No. 2	Russell's Brook, south of Main street.	Flocculent deposit, trace in suspension.	Faintly brownish.	Tasteless or slightly sw'py	Inodorous.	Faintly acid.	16.96	6.59	23.59	Nitrates.
No. 3	Russell's Brook, north of Main street, above Crane's tannery.	Flocculi suspended and deposited.	Brown shade.	Slightly of sw'p water.	Inodorous.	Neutral.	14.13	5.65	19.78	Nitrates.
No. 4	Small tributary of Horn Pond, north of Pleasant street.	No deposit.	Perfectly clear.	Tasteless.	Inodorous.	Very faintly acid.	7.53	4.70	12.23	
No. 5	Same stream as No. 4, below all the tanneries near the mouth.	No deposit.	Clear.	Tasteless.	Inodorous.	Neutral.	7.53	6.59	14.12	
No. 6	Larger tributary to Horn Pond, near its mouth and below all the tanneries.	No deposit.	Perfectly clear.	Tasteless.	Inodorous.	Faintly acid.	4.70	1.41	6.11	
No. 7	Kendall's Brook, below pond and piggery.	No deposit.	Perfectly clear.	Tasteless.	Inodorous.	Neutral.	Not determined	. . . .	1.25	
No. 8	Below Glue Factory and Cumming's tannery.	Brown flocculi in suspension and deposited.	Filtered clear.	Tasteless.	Inodorous.	Faintly acid.	10.36	6.59	16.95	
No. 9	Above Glue Factory, outlet of pond above Cumming's tannery.	White flocculi, products of beaming hides in suspension. Slight deposit.	Filtered clear.	Tasteless.	Offensive to smell.	Faintly acid.	15.08	5.65	20.73	Carb.

No. 10	Below Bishop's Extract tannery, above S. Bedford street.	Slight flocculent deposit.	Amber color.	Tasteless.	Inodorous.	Acid.	9.42	6.59	16.01	Nitrates.
No. 11	Brook above Bishop's tannery and the ponds.	No deposit.	Pale amber.	Taste of swamp water.	Inodorous.	Slightly acid.	3.76	7.53	11.29	
No. 12	Outlet of Burbank's Pond above Frye & Thompson's.	No deposit.	Pale amber.	Slight swampy taste.	Inodorous.	Faintly acid.	2.82	2.82	5.64	
No. 13	Surface of sluice water below Baeder, Adams & Co.'s Glue Stock factory.	Flocculent deposit.	Filtered perfectly clear.	Tasteless.	Faint odor of glue.	Neutral.	9.42	3.76	13.18	
No. 14	Under current of No. 13.	One-eighth a voluminous deposit.	Filtered clear.	Faint taste of glue.	Faint odor of decaying glue	Slightly acid.	8.47	7.53	16.00	
No. 15	Stoneham Brook supplying B. & A.'s Glue Stock works.	No deposit.	Perfectly clear.	Tasteless.	Inodorous.	Acid.	5.16	1.88	7.04	
No. 16	Second Race-way drain from works on the south side of brook.	Slight flocculi in suspension.	Filtered clear.	Tasteless.	Inodorous.	Slightly acid.	10.36	3.76	14.12	
No. 17	Abajonna River, 200 ft. below junction of brook and meadow receiving drainage from Glue Stock factory.	No deposit.	Brownish amber color.	Tasteless.	Inodorous.	Faintly acid.	6.14	5.16	11.30	
No. 18	Abajonna, at Stoneham Branch R. R. bridge.	No deposit.	Faint amber.	Tasteless.	Inodorous.	Neutral.	5.65	0.93	6.58	
No. 19	Junction of Wedge Pond, below Bailey's Wool Washing works.	No deposit.	Perfectly clear.	Tasteless.	Inodorous.	Very faint acid.	6.81	1.51	8.32	
No. 20	Marshy Pond below Moseley's tannery	Slight flocculent deposit.	Pale amber.	Slight swamp water taste.	Inodorous.	Very faintly acid.	3.76	2.82	6.58	
No. 21	Outlet of Wedge Pond west side of Woburn Branch R.R.	Slight brown flocculent deposit.	Pale amber.	Tasteless.	Inodorous.	Neutral.	6.59	2.82	9.41	
No. 22	Winchester Pond, west side of B. & L. & N. R. R., archway under bridge.	Slight deposit.	Pale amber.	Tasteless.	Inodorous.	Faint acid.	4.70	2.82	7.52	
No. 23	Abajonna, above Waldemayer's tannery	Slight deposit.	Clear.	Faint taste of swamp water.	Inodorous.	Very faintly acid.	4.70	4.70	9.40	
No. 24	Below Waldemayer's tannery.	Slight deposit.	Slight amber tint.	Faint taste of swamp water.	Inodorous.	Slightly acid.	5.65	1.88	7.53	
No. 25	Surface of Mystic Pond. Sample lost.									
No. 26	Surface of Mystic Pond.	No deposit.	Clear.	Tasteless.	Inodorous.	Faintly acid.	3.78	2.83	6.61	

TABLE I. — *Continued.*

No. of Sample.	Locality.	Deposit.	Color.	Taste.	Smell.	Reaction.	Inorganic Salts.	Organic driven out by heat.	Total.	General Remarks.
No. 27	Ten feet below surface.	Trace of deposit.	Clear.	Tasteless.	Inodorous.	Faintly acid.	5.67	6.62	12.29	
No. 28	Twenty feet below surface.	Trace of deposit.	Clear.	Tasteless.	Inodorous.	Faintly acid.	3.78	2.83	6.61	
No. 29	Thirty feet below surface.	Trace of deposit.	Clear.	Tasteless.	Inodorous.	Faintly acid.	3.78	3.78	7.56	
No. 30	Forty feet below surface (bottom of the Lake.)	Trace of deposit.	Clear.	Tasteless.	Inodorous.	Faintly acid.	8.11	10.03	18.14	
No. 31	Fresh Pond from faucet in Cambridge, corner of Sparks and Brattle streets.	No deposit.	Clear.	Tasteless.	Inodorous.	Faintly acid.	5.67	2.36	8.03	
No. 32	Cochituate, Revere House faucet.	No deposit.	Clear.	Tasteless.	Inodorous.	Faintly acid.	3.12	1.24	4.36	

II. TABLE OF DEPOSITS.

No. of Samples	Locality.	Description.	Smell.	Sulphuretted hydrogen.	Ammonia.	Reaction.
No. 1.	Upper Mystic, near mouth of the Abajonna.	A fine, perfectly fresh muck, and loam.	Fresh muck, no offensive smell.	None evolved on boiling with water, or with acid water.	Trace wholly neutral.	Neutral or faintly acid.
No. 2.	Abajonna, at bridge of B. L. & N. R. R.	Vegetable refuse — contains live snails.	Not offensive.	Same result as above.	Same.	" " " "
No. 3.	Abajonna, between R. R. bridge and road.	Refuse — broken glass, klinkers, some hairs.	Not offensive.	Same.	Same.	" " " "
No. 4,	Abajonna, near mouth of drain from Waldemayer's tannery.	Sand, gravel, and organic matter.	Not offensive.	Same.	Same.	" " " "
No. 5.	Immediately below Cummings' large tannery.	Sand, sticks — black deposit.	No free smell.	On boiling yields trace of sulphuretted hydrogen, and smell of horse manure.		Acid.
No. 6.	At junction of Miller and Lexington sts., above mouth of Randall's brook.	Grass, roots, little organic matter, mainly sand.	No smell.	Boiling gives no smell.	No ammonia.	Neutral.
No. 7.	Mouth of stream at Horn pond.	Except 5 per cent. all sand and loam.	No smell.	Boiling with water, no smell, nit. acid, a little.		Faintly acid.
No. 8.	Mill pond between two tanneries below Pleasant st., Woburn.	Leaves, sand, a bit of leather scraping — black deposit.	No smell.	Boiling disengages sulphuretted hydrogen, which addition of acid increases.		Faintly acid.
No. 9.	Below all tanneries on the same stream.	Bits of wood, leaves, trimmings of leather, grass. no sand, black deposit, snails. live worms: all settles out, leaving the water clear.	No smell. Filtered solution slightly offensive to taste.	Boiling sets free H S. increased by acid.		Acid — 10 parts of distilled water added to filtered water made it tasteless.
No. 10.	At outlet into Horn Pond.	Ground leather, and trimmings from beaming room, swarming with worms, grass, and organic matter. Filters nearly clear.	Trace of free smell of sulphuretted hydrogen.	Boiled gives less H S. than No. 9.	Strong acid reaction.	Same as above; filtered solution diluted with ten parts of distilled water tasteless.

II. TABLE OF DEPOSITS. — *Continued.*

Samples No. of.	Locality.	Description.	Smell.	Sulphuretted hydrogen.	Ammonia.	Reaction.
No. 11.	Russell's brook below Shaw's tannery and above the road.	Gravel, sand, ground leather.	Free smell of swamp muck: not offensive.	Boiling expelled more H S. than any previously examined deposit.	Strongly acid.	Same.
No. 12.	Russell's brook half way from road to mouth.	Leaves, stems, organic matter, ground leather, sand and gravel.	Slightly offensive on stirring.	Boiling made more offensive than No. 11, and this was increased by addition of acid.	Faintly acid.	Filtered solution, taste and smell both lost on dilution with ten volumes of dist'ed water.
No. 13.	Mouth of Russell's brook.	Sand, leaves, bits of wood, mould, ground leather.	Less offensive than No. 12. Scarcely appreciable.	Boiling freely expelled H S.	Acid.	Same.
No. 14.	Halfway from mouth of Russell's brook to Wedge pond.	Twigs, leaves, little ground leather, much like No's. 11, 12, 13.	H S. appreciable smell when stirred.	On boiling more H S. than any of all before examined, which was increased by addition of acid.	Acid.	Filtered solution a little turbid, but tasteless and odorless with ten times its volume of distilled water.
No. 15.	On side of Spy pond inlet to Fresh pond, north of road to Belmont.	Very homogeneous muck mud.	Little spontaneous smell except of muck.	On boiling and addition of acid gave off as much H S. as that from any except, perhaps, No. 14.		

It is in a degree unfortunate that a number of the manufacturing works were not in operation at the time the waters were collected, but it will be seen that the most important results arrived at would not have been materially influenced had the works all been in full operation.

THE ABAJONNA.

At the request of Mr. Moseley, proprietor of a large tannery on the Abajonna, I made a report about a year ago, upon the effect of his tannery on the Mystic water. It was made at a time when all the works on all the tributaries to the Upper Mystic were in full operation. I submit this report, with Mr. Moseley's approbation, as a part of my present report, for the purpose of comparison. It will be seen that any just inference to be drawn from the comparison is not unfavorable to the prospective salubrity of the water.

I present further in regard to the upper Abajonna the recent analyses of the water along the stream to the junction with the Wedge pond outlet: —

	Inorganic.	Organic.	Total.
From Burbank's Pond above Frye and Thompson's factory (No. 12),	2.82	2.82	5.64
From Abajonna at bridge under Stoneham branch railroad (No. 18)	5.65	0.93*	6.58
From Stoneham brook (No. 15) .	5.16	1.88	7.04
From Baeder, Adams, and Co.'s glue stock washing, upper surface of drain (No. 13)	9.42	3.76	13.18

* The small amount of organic matter, which a repetition of the analysis confirmed, supports the conviction that at or near the point where the sample was collected a spring enters the stream. That the waters of the several streams to some extent preserve their individuality for a time, after joining the main trunk, seems highly probable.

From Baeder, Adams, and Co.'s glue stock washing, lower current of drain (No. 14)	8.47	7.53	16.00
From Baeder, Adams, and Co.'s glue stock washing, southerly drain (No. 16)	10.36	3.76	14.12
From a point 200 feet below junction of Stoneham brook with Abajonna (No. 17)	6.14	5.16	11.30
Abajonna just above Moseley's tannery (No. 1)	4.70	3.76	8.46
Winchester pond, 700 feet below Moseley's tannery (No. 20) .	3.76	2.82	6.58
Winchester pond, west side of Boston and Lowell railroad (No. 22),	4.70	2.82	7.52
Outlet of Wedge pond (No. 21) .	6.59	2.82	9.41
Abajonna, below Main street and above Waldemayer's tannery (No. 23)	4.70	4.70	9.40
Abajonna, below Waldemayer's tannery (No. 24)	5.65	1.88	7.53
Surface of Mystic pond (No. 26) .	3.78	2.83	6.61
Last year in same month at Gate House it was	3.94	1.36	5.30

Of these samples of water No. 13 has faint odor of glue stock; No. 14 is offensive to the sense of smell; Nos. 12, 20, 23, and 24 have faint taste of swamp-water. All are substantially tasteless. Most are neutral or have a very faint acid reaction to delicate test paper.

DEPOSITS AT THE BOTTOM.

It might be supposed that the mud or earth at the bottom would, as the representative of organic residual matter, finding its way into the river and lake, be found capable of yielding an offensive extract.

A sample of the bottom of the Mystic pond, near the mouth of the Abajonna, is, on drying, a fine, fresh muck loam. On boiling it with water it does not yield a trace of sulphuretted hydrogen or of ammonia; — acid disengaged no sulphuretted hydrogen from the air-dried mud.

A sample from near the mouth of the drain from Waldemayer's tannery contained sand, gravel, and organic matter. It yielded on boiling with water no trace of sulphuretted hydrogen or appreciable ammonia. Boiled with acid it yielded no sulphuretted hydrogen.

A sample of deposit from the Abajonna at the crossing of the Lowell railroad, and below Moseley's tannery, contained fine, earthy matter, live snails, and vegetable refuse. It yielded on boiling with water not a trace of sulphuretted hydrogen or of appreciable ammonia. Acid treatment of the air-dried mud gave no sulphuretted hydrogen.

A sample of bottom deposit at a point higher up contains slag, broken glass, some hairs, and earthy matter. Like the others on boiling with water it yielded no trace of sulphuretted hydrogen or of appreciable ammonia. Boiling with acid gave no sulphuretted hydrogen.

The examinations for free sulphuretted hydrogen were made when the deposits were fresh. The examination for latent sulphuretted hydrogen — that is, sulphuretted hydrogen combined with bases — was not made till the muds had been for some weeks exposed to the air. It is, therefore, possible that the sulphides had become oxidized to sulphates. As their decomposition and the disengagement of sulphuretted hydrogen involves the presence of acid in the water, which may be said to be uniformly wanting at the points where the deposits were collected, there is no just fear that the sulphides would have taken any other course in their natural position than that they took on drying after collection.

These deposits, if they may at any time have had capacity to yield offensive matters to the water above, have lost it.

Indeed, they are below the point to which any contributions of what may be regarded as offensive solid matter made above them, are carried by the current. Or, if they have reached these points, the present condition of the deposits illustrates the reserve of self-purifying power of the water that flows over them.

These determinations justify the inference that whatever comes into the river above these points of a nature to yield sulphuretted hydrogen or other offensive gas in progressive decay, has been oxidized and destroyed by the self-purifying power of the water itself. It leaves us justified in inferring that at all times, if there should be a trace of parent material for evolving sulphuretted hydrogen in the mud, as there always is when a worm or fish dies and falls to the bottom of a lake or pond, it will be speedily destroyed by the water and the air it contains in solution.

THE GLUE STOCK MANUFACTORY

derives its supply of water from a small tributary to the Abajonna, known as the Stoneham brook. These works gather up the scraps and trimmings of hides from tanneries, treat them with lime to separate the hair where it has not before been removed, wash and clean them, and send them to market. It is understood that the works are soon to be enlarged and joined on the spot with a large glue factory.

The composition of the Stoneham brook residue is: —

	Inorganic.	Organic.	Total.
In one gallon	5.16	1.88	7.04
The surface of one drain from the works contains in one gallon .	9.42	3.76	13.18
The bottom of the same drain contains, separated from the deposit, in one gallon . .	8.47	7.53	16.00
The water from the sluice south of the Stoneham brook contains in one gallon . . .	10.36	3.76	14.12

At present the washing of the scrap is attended with the removal of some soluble and a little insoluble organic matter, which is received into sluiceways leading to a meadow where the water is filtered through a considerable margin of swampy meadow before reaching the channel of the Abajonna.

	Inorganic salts.	Organic.	Total.
Above the site of this factory the composition of the water of the Abajonna is in one gallon . .	5.65	0.93*	6.50
Below the meadow . . .	6.14	5.16	11.30

Here is a manifold great increase of organic matter, but the analysis of the water a mile further down, just above Moseley's, shows that the organic matter has been largely destroyed and the inorganic diluted.

	Inorganic.	Organic.	Total.
One gallon contains . . .	4.70	3.76	8.46

The organic matter at Burbank's pond, above all the influence of the factories, is 2.82 grains, only one quarter less.

The future erection of extensive glue works will demand greater service of the filtering power of the meadow below. How much, will depend somewhat on the care with which the manufacture is conducted. The works that are to be brought here have been for some time in operation on Cummings' brook, below Cummings' tannery. We have, therefore, had their influence on the water of the Mystic ever since the period of its introduction. The effect they have produced hitherto was merged with that of Bishop's and

* The small amount of organic matter, and the relatively large amount of inorganic matter, seem exceptional, — perhaps they point to a spring at this point, as already suggested.

Cummings' tanneries, which will be considered in their place. The distance the water will flow before reaching the Upper Mystic from Stoneham brook and the ponds through which it must pass will be about the same as they have been hitherto. I see no reason why the ill effect of production in one locality should exceed that in the other.

For the further consideration of the influences tending to deteriorate the Abajonna, I beg to refer to the accompanying report in regard to the influence of Mr. Moseley's tannery.

THE TRIBUTARIES TO HORN POND.

The water of the brook (No. 7) flowing near the great piggery, and emptying into Kendall's pond, is a water of primitive purity. Below the pond, but above the junction with Cummings' brook, it contains in one gallon,

Inorganic.	Organic.	Total.
Not determined.	.....	1.25

Water from Cummings' brook above all the factories on this stream contains in one gallon,

Inorganic.	Organic.	Total.
3.76	7.53	11.29

Now, had this water been taken from below any of the factories, it would have occasioned solicitude. But when we consider the large amount of organic matter in the sources of the stream at this season, — mainly the extract of falling leaves, — the explanation of the fact is furnished us.

Below Bishop & Co.'s tannery, where extracts of bark, elsewhere concentrated, are used, the bed of the settling pool and the bed of the stream are overspread with black powder from the extract. The water was collected when the tannery was in operation, though not so fully as it is at some times.

It (No. 10) was taken from the bed of the brook at South Bedford-street crossing, above the little pond nearest Cummings' tannery.

	Inorganic.	Organic.	Total.
One gallon contains,	9.42	6.59	16.01

The organic matter is less than it was above Bishop & Co.'s tannery, but the inorganic matter has increased.

Immediately below Cummings' tannery, but above the junction of the glue factory sluiceway, the water (No. 9) contains,

Inorganic.	Organic.	Total.
15.08	5.65	20.73

Below the junction of the sluiceway from the glue factory — where little was going on — and where, therefore, we have the influence chiefly of the running stream on the water of (Nos. 10 and 9), we find in one gallon,

Inorganic.	Organic.	Total.
10.36	6.59	16.95

Just above the mouth of this brook, but below the pure tributary of Kendall's pond, after flowing less than half a mile, we have a water (No. 6) absolutely tasteless and inodorous, and containing in one gallon,

Inorganic.	Organic.	Total.
4.70	1.41	6.11

That of the upper Mystic, near the Gate-house, is not greatly different. It contains of

Inorganic.	Organic.	Total.
3.78	2.83	6.61

In the deposit at the mouth of Cummings' brook, where it empties into Horn pond, and where any mud not already de-

posited, feels the quiet of the still water and settles to the bottom — the total amount of organic matter was a little above five per cent., the balance being beach sand. It yielded no trace of sulphuretted hydrogen or ammonia. The suspended organic matter from the tanneries had all, long before, settled out.

Immediately below Cummings' tannery the mud yields sulphuretted hydrogen and has an exceedingly offensive look and smell; but at the corner of Lexington and Willow streets, less than a quarter of a mile below, the deposit collected at the bottom of the stream was mainly sand, grass and roots, and yielded no sulphuretted hydrogen or ammonia.

The just inference from these determinations seems to be that the power on the part of the factories above to injure the water, so far as organic matter is concerned, is neutralized before the waters reach the lake. In this case the activity of the works was perhaps less than usual; Cummings' establishment, the most extensive, however, seemed to be in full action.

The inorganic matter that is added from these works is chiefly common salt from the hides, which, unless in very large quantity, does not increase the hardness of the water, or impair it in any way for domestic use.

STREAM CROSSING PLEASANT STREET, NEAR WATER STREET.

The water above Pleasant street (No. 4, Table I.) contains the normal water-shed, to which is doubtless added some drainings from the district above. One gallon contains,

Inorganic.	Organic.	Total.
7.53	4.70	12.23

At the mouth of the stream but a short distance below where it empties into Horn pond (No. 5, Table I.), one gallon contains,

Inorganic.	Organic.	Total.
7.53	6.59	14.12

Between the two localities are the tannery of Stephen Dow & Co., and the sheep-skin works of Mr. Davis (not in operation).

Mud (No. 8, Table II.) from the bottom of the pond between these points contained powdered leather and scrapings of leather. It gave off spontaneously no odor of sulphuretted hydrogen, but did on boiling, and more on boiling after the addition of hydrochloric acid.

Mud (No. 9, Table II.) from below Davis's works contained trimmings of leather, grass, shavings, bits of wood, live worms, snails, and no sand. Settled clear from the water, leaving the water slightly offensive to taste. The sand had no offensive smell. On boiling with water it gave off sulphuretted hydrogen, which was increased on the addition of hydrochloric acid. The clear solution diluted with ten times its volume of pure water became tasteless.

The deposit (No. 10, Table II.) from the bed at the mouth of the stream where it empties into Horn pond is a mass of organic refuse, scraps of leather, of trimmings apparently from the beaming-room (untanned scrapings), leaves and grass; the whole, and especially the untanned scrapings of hides, swarming with small worms, evidently in a short time destined to consume the fresh tissue.

The smell was offensive, and the presence of sulphuretted hydrogen on boiling appreciable, and rendered more so by addition of acid. The deposit settled out, leaving the liquor above quite clear and but slightly offensive to taste. To this the addition of ten volumes of pure water was enough to render it tasteless.

Water (No. 3) taken from Russell's brook, below numerous tanneries, contained in one gallon,

Inorganic.	Organic.	Total.
14.13	5.65	19.78

Water (No. 2) from below Shaw's tannery, the nearest in this stream to the junction of Russell's brook with the outlet from Horn pond, and below the road, contains in one gallon,

Inorganic.	Organic.	Total.
16.96	6.59	23.55

The deposit (No. 11, Table II.) from just above the road and a short distance above the point where the water (No. 2) was taken, contained gravel, sand, muck and ground leather. Gave off freely sulphuretted hydrogen. The liquid extract filtered from the solid part lost its offensiveness to taste in ten volumes of pure water.

The deposit (No. 12, Table II.) from immediately below the road contained the same ingredients, with smaller proportion of sand and gravel, and was decidedly more offensive to smell. Like all the offensive muds, it was acid. The taste and smell were both lost on dilution of the filtered water of the deposit with ten times its volume of pure water.

The deposit (No. 13, Table II.) from the mouth of Kendall's brook was much less offensive than No. 12, a few rods above. It contained more leaves, bits of wood, mould and some sand. The filtered water of the deposit lost both taste and smell in ten times its volume of pure water.

The deposit (No. 14) from the outlet of Horn pond, half the way to Wedge pond, contained ground leather, twigs and leaves. Gave off on boiling more sulphuretted hydrogen than any of the preceding samples ; yet ten times its volume of distilled water rendered the water filtered from its deposit tasteless and odorless.

The water (No. 19) near the point where this mud was collected, and in the regular outlet of Horn pond, below the mouth of Russell's pond, and above the Wedge pond contains in one gallon,

Inorganic.	Organic.	Total.
6.81	1.51	8.32

Notwithstanding the objectionable character of the bed of the stream, as shown in deposit No. 19, the organic matter has fallen to a minimum.

The water (No. 21) at the outlet of Wedge pond, below the sheep-skin washing, contains in one gallon,

Inorganic.	Organic.	Total.
6.59	2.82	9.41

The water above Waldemayer's on the Abajonna (No. 23) contains in one gallon,

Inorganic.	Organic.	Total.
4.70	4.70	9.40

Below Waldemayer's (No. 24) it contains,

Inorganic.	Organic.	Total.
5.65	1.88	7.53

At the Mystic pond (No. 26) one gallon contains,

Inorganic.	Organic.	Total.
3.78	2.83	6.61

As bearing on the significance of the results of examining the muds and deposits, I visited Fresh pond and collected from the side of the inlet from Spy pond, north of Belmont road, below the surface of the water, the black mud which borders this inlet through the marsh. It was to the eye a mass of fine, black swamp mud. But on treating it as the

muds from the inlets to Horn pond were treated, it disengaged sulphuretted hydrogen very much in the same way, and was in respect of offensiveness to the sense of smell not inferior to most of them. Now, this long stream from Spy pond to Fresh pond lies in a body of muck saturated with the sulphates of ancient sea-water carried up by high tide, and which must for an indefinite time to come continue to act as it now does. Yet I am disposed to think it is equally true that no sulphuretted hydrogen ever reached the Fresh pond surface-water from this source, or from any other source.

I have carefully examined the water of the Upper Mystic pond, from the surface to the bottom, without finding in it any trace of sulphides, or enough of chlorides to indicate their presence by the test of sugar of lead, though the addition of silver salt reveals them.

At the time of Silliman's analysis in 1862, there seems to have been a larger amount of salt in the lower portions of the body of water than there is now.

Thus: Silliman found the surface-water near the site of the present Gate-house to contain in one gallon a total of 9.58; at a depth of 18 feet, the saline matter 15.68; and at a depth of 50 feet, 63.58.

At the same time he found the water nearly opposite the then residence of Mr. Everett, at the mouth of the Abajonna, to contain only 3.22.

But the analyses of five samples recently collected at intervals of ten feet from the surface to the bottom have given a better result for the lake, indicating, perhaps, the influence of the low water during the last summer in diluting the deeper water.

	Inorganic.	Organic.	Total.
At the surface one gallon gives .	3.78	2.83	6.61
Ten feet below (repetition gave the same result) . . .	5.67	6.62	12.29
Twenty feet below . . .	3.78	2.83	6.61

Thirty feet below	3.78	3.78	7.56
Forty feet below	8.11	10.03	18.14

The chief foreign inorganic matter in the water is common salt, with a lesser proportion of sulphates of soda, lime and magnesia, and occasional small quantities of nitrates and carbonates.

SUMMER DROUTH.

In the summer of 1872 numerous analyses of the Mystic water were made by Prof. Chandler of Columbia College, and Pres. of the New York City Board of Health, and by S. Dana Hayes, Esq., of Boston. Two analyses of water, collected late in July by Mr. Hayes, gave an average of total in one gallon, inorganic and organic together, . . 5.62 grains.

An average of seven made early in August, by Prof. Chandler, gave . . .	5.72 "
An average of three, by Mr. Hayes, in September, gave	5.68 "
My own determinations in November of the same year gave, for the water at the Gatehouse	5.30 "

The details are given in the accompanying report upon the influence of Moseley's tannery. At the time my determinations were made, Mr. Sawyer found 42,272,000 gallons for the daily flow of the Abajonna at its entrance to the Mystic. This is undoubtedly above the average. The report of Messrs. Kirkwood and Francis gives the rain-falls in Cochituate basin, for 1871, as follows: —

For July . . .	0.48 of an inch.
" August . . .	0.90 " "
" Sept. . . .	0.67 " "
" Oct. . . .	0.97 " "
" Nov. . . .	1.61 " "

And they assume for the Mystic, in a season of drouth for these months, as follows: —

For	July	0.30
"	August	0.50
"	Sept.	0.60
"	Oct.	1.00
"	Nov.	1.80

If these be something near the relative amounts of rain-fall for the several months in average years, the foregoing analyses acquire a new significance. They leave us to infer that, notwithstanding the probable unusual dilution of the organic and inorganic matters in November, the higher temperature of the summer intensifies the self-purifying power of the water, and so as effectually consumes the organic matter as a larger volume of lower temperature would do.

The average organic matter of all the analyses of Chandler and Hayes for July, August and September, was for each gallon only 1.90 grains.

From my own analyses on the line of the Abajonna, from the pond above the lace-leather factory (Burbank's pond), that is above all the factories down to and including the water at the entrance to the aqueduct — five samples in all — the average was for each gallon 1.15 grains.

During the summer and fall of 1872, that is the period when the above determinations of Prof. Chandler, Mr. Hayes and myself were made, all the factories were in operation.

Now, when a part of the factories are suspended, and the water at least more abundant than in summer, the organic matter at the mouth of the Abajonna, and at the surface of the Mystic, is for each gallon 2.83 grains.

Now take the organic matter in the upper waters of Cummings' works in Nov., 1873 (No. 11), 7.56 grains.

And at a point north of Pleasant street, above Dow's fact tory, of the same date, at 4.70 grains.

And at Burbank's pond, above the factories on the Abajonna, at 2.82 grains.

And immediately below Baeder & Co.'s glue stock washing works, at 5.16 grains.

And compare them with the organic matter in the water at the Mystic lake, 2.83.

And the result is satisfactory as showing the self-purifying power of the water.

Compare, too, the organic matter of the previous year.

At Burbank's pond it was, a year ago, 0.95 grains,

And after all the accessions below at the entrance to the aqueduct, only 1.36 grains.

Chemistry certainly does not furnish any ground for distrusting, at any season of the year, the self-purifying power of the water with only the present agencies of contamination.

NATURE OF THE ORGANIC MATTER, AND HOW NATURAL AGENCIES REMOVE IT.

The organic matter, of the nature of tan bark, which is substantially of the same character as the extract of leaves and bark drained from the surface of wooded lands, must be regarded as harmless. It is speedily consumed by the self-purifying power of a running stream. When combined with gelatine to form leather it is practically insoluble, and so of course harmless, when the results of scouring the tanned hides reach the water bed, unless the quantity be something very great. Leather bags for carrying drinking-water are extensively employed and leather cups for its service are in use the world over.

Where shreds of untanned hides from the beaming-room through carelessness reach the water, they speedily disappear, as do the bodies of fish that perish in ponds or streams from disease or old age. Nature provides scavengers for them. If not promptly consumed by minute organisms of inferior

order to be resolved into nearer approaches to inorganic bodies, and so rendered inoffensive and harmless, the same end is accomplished by oxidation, as in the case of sewage. The self-purifying power of running streams, reinforced along their course by springs, is one of the great economical agencies of organic life. There is a limit to it, of course, but from this limit chemistry indicates that the Mystic is yet far removed. There seems to be no ground for believing that appreciable organic matter, of a character to render the water insalubrious, reaches Charlestown or Somerville, or Chelsea or East Boston, from any manufacturing establishment in the basin of the Mystic.

If the existing factories in the Mystic basin are to be enlarged in the future, and new ones are to be added, and the region surrounding them to become more densely populated than it now is (which seems certain), I can conceive a time coming, when, in seasons of drouth, bringing low stages of water in the streams, while the agencies of impurity remain constant, the drainage from the manufactories and domestic sewage would overtask the self-purifying power of the water.

The relief to be sought in view of such a contingency is, of course, independent sewage for both factories and dwellings, discharging below the Lower Mystic within the reaches of the sea.

SUMMARY OF CONCLUSIONS.

1. Of the fitness of the Mystic water for boiler use, judging from a comparison of the amount of its organic and inorganic matters with that of these ingredients in the waters of Lake Cochituate and the Croton, there seems to be no doubt. The results of inquiries conducted by the Water Board have, I understand, proved satisfactory.

2. Of its fitness for domestic use in the laundry, it is substantially what it was at the time of its introduction, a remarkably soft water.

3. Of its salubrity as a drinking water, it will compare well with the best waters in use for city supply. It has experienced no appreciable deterioration since its introduction.

4. If the contributions from factories and domestic sewage continue to be no greater than they are now and have been hitherto, and the volume of water remains the same, the self-purifying power of the water will be adequate to maintain its salubrity.

5. In case the factory drainage and domestic sewage discharging into the tributaries are steadily increased, and especially if the supply of water be from any cause diverted or diminished, a time will come when the self-purifying power of the water will be overborne. When such time comes independent drainage for the factories and domestic sewage to a point below the entrance to the aqueduct will restore the balance.

Respectfully submitted,

E. N. HORSFORD.

CAMBRIDGE, Dec. 30, 1873.

REPORT

ON THE

EFFECT OF MOSELEY'S TANNERY

ON THE

SALUBRITY OF THE MYSTIC WATER.

1873.

REPORT ON THE SALUBRITY OF THE MYSTIC WATER.

To find the effect of Moseley's tannery on the composition of the water of the Charlestown Water Works, it is necessary to know: —

1st. The composition of the water immediately above the tannery; and

2d. That of the water below the works before the addition of water from any new source;

3d. The volume of water passing through the tannery and discharging into the Abajonna;

4th. The composition after passing through the tannery, and before discharging into the river;

5th. The effect upon this water of discharging it into the larger volume of the Abajonna;

6th. The volume of water passing through the aqueduct, and over the dam and river at the gate-house.

For the better understanding of the whole subject it is desirable, in addition, to take into account the composition of the water of the Abajonna at a point above any manufacturing establishments that may be charged with adding foreign matter to the stream; also, that of the water at the mouth of the Horn pond stream or Wedge pond outlet; the larger source of the supply to the upper Mystic pond before it united with the Abajonna below Moseley's; and, lastly, of the water as it enters the aqueduct at the Gate-house.

I accordingly collected water: —

1st. From the Burbank pond, above the lace-leather fac-

tory, or Frye's tannery, about two miles from Moseley's tannery, toward the sources of the Abajonna.

2d. From under the bridge of the highway, crossing the Abajonna immediately above Moseley's tannery.

3d. From the archway of the Boston and Lowell railroad, below the tannery.

4th. From the head of the drain leading from the tannery into the Abajonna.

5th. From the mud at the bottom of the drain.

6th. From the still water over the delta at the mouth of the drain.

7th. From the mouth of the Horn pond stream, in the archway of the Woburn Branch Railroad.

8th. From the Gate-house.

Numbers five and six were collected on the 15th of November last (1872); all the others on the 26th.

The water from the pond on the Abajonna, above the lace-leather factory, — the normal water of the drainage of the Mystic basin, — contains of grains in one gallon,

Salts.	Organic matter.	Total.
2.27	0.95	3.22

Between this pond and Moseley's tannery there are several manufacturing establishments, including an extensive glue stock factory.

There are several ponds and marshes on the stream, all the waters of which pass under the highway bridge immediately above Moseley's tannery, and at a short distance from the mouth of the pump pipe, through which water is drawn for the main supply of the reservoirs of the tannery.

At that point below the bridge, I collected water for analysis. It contained in one gallon,

Salts.	Organic matter.	Total.
3.21	1.04	4.25

Mr. Moseley's tannery is situated on a little rise of land, on the right bank of the stream; and directly below the establishment a pond spreads out, through scattered swamp shrubbery, chiefly on the right side of the river, like the loop of a capital P, while the main current of the stream preserves its course to the left of the pond. This pond gives great stillness to the water into which is delivered the drainage from the tannery.

Between the tannery and the water is a margin of swamp muck, which has been covered with spent tan bark. Within this strip of land, above high-water mark, is a long line of parallel and connected trenches, which has been dug to allow the wash water from the scouring and beaming of the leather and hides to settle. At the end of it, where it discharges into the drain, is a charcoal filter, through which the water, after slowly flowing through a channel a thousand feet long, must finally pass. Beyond the charcoal filter it unites with water from the other parts of the tannery and passes through the open drain to the pond below the works. The soil under the tan bark is saturated with the extract of the tan bark, and to some extent, this extract finds its way to the drain and the pond below.

Near the lower end of the pond lying in the bayou below the factory, the water passes through an arch under the Boston and Lowell Railroad. It carries with it the total effect of the Moseley tannery.

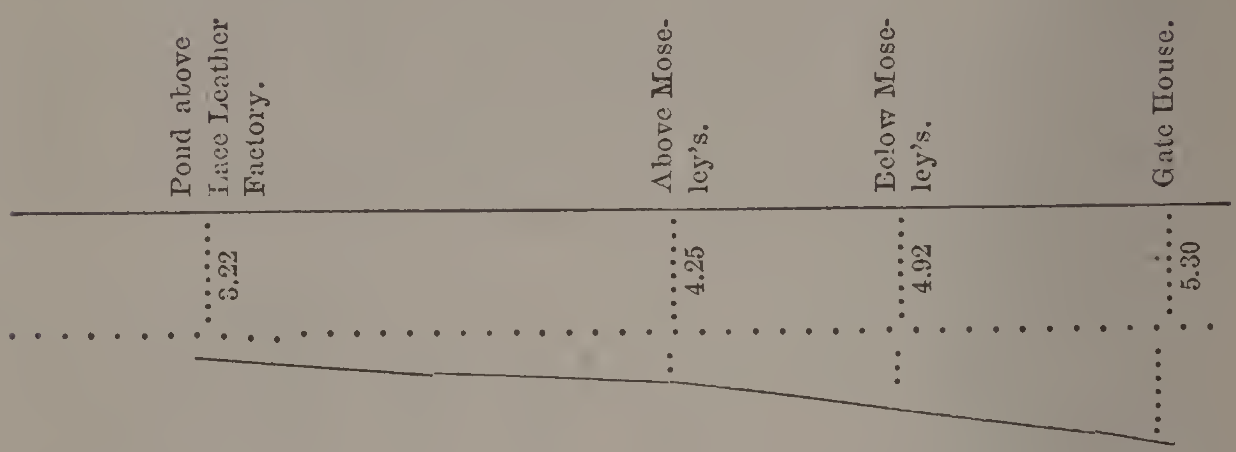
I collected the water of the Abajonna where it enters the archway under the Lowell Railroad. It contains in one gallon,

Salts.	Organic Matter.	Total.
3.22	1.70	4.92

A gallon of water collected at the Gate-house contains,

Salts.	Organic Matter.	Total.
3.942	1.36	5.30

From these results a profile may be drawn which will illustrate the changes in the composition of the water.



It now appears that more than three-fifths $\left(\frac{3.22}{5.30}\right)$ of the foreign matter in solution at the Gate-house is due to the incidental and inevitable drainage of the soil of the Mystic basin *above all* the factories.

Of the remaining (less than two-fifths), the share contributed by Moseley's tannery will appear from the following: The open drain leading from the tannery is about one hundred and fifty feet long, and presents a dead level of pulpy, yellowish and dark-reddish mud, offensive to the sight, and such as to induce a superficial observer to infer that the works must more or less injure the water. The light granular matter so objectionable to the eye is found, however, not to be especially offensive to the taste or smell.

It proves, on examination, to be mainly composed of fine particles of leather, removed in the scouring process. The smell is that of new leather, with no smell of decomposition; and the taste that of leather and salt.

The extent of the possible injury to the water from the matters discharged into the drain has been subjected to determination.

Mr. Sawyer found, as the result of prolonged hydraulic observations, that the water discharged through the common drain of the tannery amounts to 13,000 gallons in twenty-four hours

The remaining water pumped from the Abajonna, and the well water used in the works, passes off as steam or by evaporation from the drying leather.

A hundred hides a day are introduced into the tannery with whatever salt they contained to preserve them. This salt, which varies in quantity with the season, weight of the hides, and time they must be kept in the green state, is estimated to average, as I have learned from various slaughter-houses and tanneries, ten pounds for each hide. All this passes into the drainage. The water is employed in the various processes of tanning and dressing the hides. The tan vats are not emptied, but the liquor is used to extract fresh bark to keep up its strength. The main body of water used in beaming and dressing, with its fine fibrous matter, passes into a long canal, already mentioned, of about 1,000 feet, to settle before going through a charcoal filter into the drain. The matters which settle in this canal are from time to time shovelled out and sold to farmers. So completely is the lime employed to remove the hair combined with gelatinous matter and deposited in the canal, that the water which flows through the charcoal filter contains only a trace of it. At the head of the open drain the wash water comes in from other parts of the factory, containing the product of scouring the leather.

Analysis of the mixed drainage water, received in a temporary flume, was made. It is a dirty, brownish-yellow liquid, owing its color principally to tan liquor. Its chief taste is that of salt with a flavor of new leather. Its odor is mainly that of tan-bark, or of new leather. A gallon contains,

Salts.	Organic Matter.	Total.
628.4	100.4	728.8

This water, on being diluted with four parts of pure water, is only slightly brackish, but still colored. Diluted with eighty parts of pure water, it is but faintly clouded, perfectly

tasteless, and settles clear in a few days. Diluted with four hundred parts of water, it becomes colorless, tasteless, and clear at once.

The flow of water from the temporary flume at the time this water was collected was about three gallons per minute; at times the discharge rises to much above this rate, and at others it sinks to less than a quart.

On one occasion, when the quantity of water entering the drain was so small as to be scarcely recognizable, I collected the reddish, muddy liquor of the drain, from which the previously suspended insoluble substances had settled out, at a point some thirty yards towards the mouth of the drain from its head.

The water drained from the suspended matters was of a cherry-red color. Its odor was of tan bark, and its taste of new leather and salt.

One gallon contains: —

Salts.	Organic matter.	Total.
352.2	102.1	454.3

This liquor deposited continually. On dilution of one part with ten of clear water it lost most of its cherry color, and with one part diluted with one hundred parts of pure water it became perfectly clear.

On examining the ground on either side of the drain it was obvious that the extract of tan bark or new leather came from the dripping of hides hung up to dry over the spent bark covering the muck, and, doubtless, also from the rain falling on and soaking through the tan bark.

On the same day that the water from the bottom of the drain was collected, I noticed that at a little distance, and within a few feet of the mouth of the drain, and over the delta of leather scourings settled out, the water in all directions toward the pond was clear. By suspending a bottle

from the end of a hoop-pole, while standing on the shore, I collected a sample of the water immediately over the delta where the clear water was less than a foot in depth. It was to the eye clear, and to the palate tasteless as the best pond water. On careful examination it was found to contain now and then a trace of still suspended fibres of organic matter.

Analysis showed it to contain: —

Salts.	Organic matter.	Total.
4.54	8.23	12.77

These results show how, and how rapidly, the accumulated impurities of the drain fade away. Most of the fine particles of ground leather sink. The extract of the tan bark rapidly dilutes and becomes colorless. The heavier salt water sinks into the soil below, so that according to the results of analysis its effect at the archway of the Lowell Railroad is scarcely appreciable (3.21 : 3.22). The quantity varies with the intermittent operations of the tannery. When the water from a batch of fresh hides is run off, the salt in the water will be abundant, but the maximum average admits of easy calculation; at ten pounds to a hide, with a hundred hides a day, each of the 13,000 gallons passing through the tannery daily would contain one-thirteenth ($\frac{1}{13}$) of a pound daily, that is 590 grains.

Now, assuming that the whole of this salt — one thousand pounds for each work day — is added to the Abajonna, and is uniformly diluted through the whole water passing out of the Upper Mystic pond each twenty-four hours, over the dam and weir, and through the aqueduct at the Gate-house, it is easy to calculate this effect of Moseley's tannery.

Mr. Sawyer found this volume of water to be 42,272,000 gallons per day.

Divide the grains in a thousand pounds by this volume, and we shall have the weight of salt for each gallon. It amounts to (0.18) eighteen hundredths of a grain per gallon.

But this analysis of the water at the archway under the Lowell Railroad shows, as does that at the Gate-house, that a small fraction only of the salt water mingles with the stream, the balance, by reason of its greater specific gravity, holding its place *below*.

The analyses are obviously perfectly conclusive on this point, but it may be well to illustrate the subject.

The soil of the region is porous, gravel and sand; water sinks readily through it until it reaches the rock below, or the level of the pond, and then flows along to the pond; salt water takes the lower position, displacing the lighter water, just as the salt water of spring tide runs in at the outlet of the Lower Mystic, and flows under the sweet water at the surface. The same takes place, or formerly took place, at Fresh pond and Spy pond. As an illustration of this, I submit the results of an examination made by me, in 1860, in a report made to the Harbor Commissioners upon the Mystic-pond water. This shows that in the Lower Mystic the sweet water extends downward about twenty feet, while below that evel, throughout the pond, the water is increasingly salt. The same condition, to a less extent, prevails in the Upper Mystic, separated by a ridge of sand and gravel from the lower pond. It was observed by Silliman, and he reports to the Water Commissioners, in 1862, that the water at the surface contains, for each gallon, 7.50 grains of saline matter.

At a depth of 18 feet from the surface 15.68 grains.
And at a " " 50 " " " 63.58 "

This condition doubtless prevails now. That is, strongly saline water finds its way at once to the lower level, and, in many cases, doubtless pursues an underground drainage to the lowest level, mingling but slightly with the surface water. Accordingly, we find the effect of the saline matter of Mr. Moseley's tannery to be practically inappreciable at the Gate-house.

Common salt, except in quantity so large as to make the

water brackish to the taste, is not harmful. It does not make water hard, as lime and magnesia salts do, for washing purposes.

The addition of organic matter, which is chiefly extract of tan bark, and is substantially of the same nature as that of the ordinary drainage of forest land, is a harmless constituent, and is by natural process continually oxidizing and disappearing as water and carbonic acid.

The experiment of dilution and settling performed in the laboratory, and resulting in rendering the water clear and palatable, is constantly carried on, only to greater and more satisfactory extent, as the water of the drain from Moseley's tannery is mixed with and diluted by the still water of the bayou into which the drain discharges.

The water of the mouth of the Horn pond stream, before its junction with the Abajonna, contains the same amount of organic matter that the Abajonna does, but the saline constituents are larger in quantity. One gallon contains,

Salts.	Organic matter.	Total.
4.17	1.70	5.87

From the junction to the Gate-house the foreign matter diminishes by half a grain to the gallon, of which the organic matter forms the larger part. In other words, the organic matter is diminished by oxidation, and the saline matters of the Horn pond stream diluted by the purer water of the Abajonna.

The changes in composition will better appear from a comparison. Of grains, one gallon contains,

	Salts.	Org. matter.	Total.
Pond above Lace-Leather factory .	2.27	0.95	3.22
Bridge above Moseley's tannery .	3.21	1.04	4.25
Archway L. R. R. below " .	3.22	1.70	4.92
Horn pond stream . . .	4.16	1.70	5.87
Gate-house	3.94	1.36	5.30

Analyses of the water at the Gate-house and its neighborhood have been made during the past summer, and at previous periods, and may be placed on record with profit in enabling us to form a correct judgment as to the present condition of the water.

The foreign matter found by Mr. S. Dana Hayes in samples taken from different points gave (Boston City Doc. No. 89, Sept. 9, 1872),

No.	Samples.	Salts.	Org. matter.	Total.
1.	July 16th.	3.75	1.91	5.66
2.	" "	3.78	1.90	5.68
3.	" "	3.79	1.91	5.70
4.	July 26th	3.82	1.90	5.72
5.	" "	3.68	1.84	5.52

BY PROF. CHANDLER.

No.	Samples.	Salts.	Org. matter.	Total.
6.	August 3d	3.81	1.96	5.77
7.	Average of 6 analyses	3.77	1.90	5.67

'Another by Prof. Chandler gave,

Salts.	Org. matter.	Total.
4.199	1.633	5.832

The last, by Prof. Chandler, corresponds almost precisely with my analysis of the Horn pond stream at its mouth, above the junction of the Abajonna. It gave,

Salts.	Organic matter.	Total.
4.16	1.70	5.87

In 1860 I had occasion, as already mentioned, to analyze the surface water of the Upper Mystic pond from a point near the site of the present dam and Gate-house. (Report of Boston Harbor Commission, 1861.) One gallon contained, Sept. 10th, 1860,

Salts.	Organic matter.	Total.
8.43	3.40	11.83.

Prof. Silliman in his report on the Upper Mystic pond water, in 1862, gives an analysis of water "from the surface of the pond, about 300 feet from the west shore, on Wyman hill line." One gallon contained, May 23d, 1862,

Salts.	Organic matter.	Total.
7.50	2.08	9.58

These quantities, it will be seen on comparison, happened to be about double the quantities *now* present in the water, and yet they compare favorably with water of acknowledged excellence for domestic uses.

Prof. Silliman's analysis of water of the Croton Upper Reservoir gave, 1845,

Salts.	Organic matter.	Total.
6.66	4.28	10.93

Schuylkill water of the same period gave,

Salts.	Organic matter.	Total.
4.26	1.24	5.50

The results of the foregoing investigation may be thus summed up: —

1st. The normal amount of foreign matter in the Charlestown Water Works' water, due to the natural drainage of the Upper Mystic basin, above all factories, is

3.22 grains to a gallon.

2d. The addition to this amount from all sources connected with the use of the water on all the streams flowing from the basin, is

2.08 grains to a gallon.

3d. Of this 2.08 grains, nearly four-fifths (1.67 grains) is little else than common salt.

4th. Of this common salt Moseley's tannery contributes less than two-hundredths of a grain to the gallon.

5th. The organic matter discharged from Moseley's tannery is for the most part insoluble, and is not permitted to enter the stream, but settles out in a long settling canal, and is from time to time removed. Of the portion that is soluble, the greater part is of the nature of extract of leaves and bark, which is common to all surface waters draining forest lands, and rapidly oxidizes and disappears on dilution with running water.

The water at a few yards from the mouth of Moseley's drain is tasteless, and clear and soft, and suitable for all domestic purposes.

6th. The proportion of organic matter contributed by Moseley's tannery to that contained by the water at the gate-house, cannot be more than five-thousandths ($\frac{5}{1000}$) of a grain to a gallon.

(Signed,) E. N. HORSFORD.

CAMBRIDGE, Dec. 25, 1872.

Report on Waste Water.

REPORT ON WASTE WATER.

John A. Haven, Esq.,

President of the Cochituate Water Board: —

Sir, — The order of the City Council, addressed to the Cochituate Water Board in October, for information as to resources for "further supply of water," etc., etc., closes as follows, — "and the changes needed to prevent any waste of the present supply." This branch of the order having been referred to the Water Registrar, he would respectfully

REPORT:

That the permanent, serious and continual causes of waste of Cochituate water are through the use of hopper water-closets; the so-called self-acting closets; urinals which are constructed for a continual run of water; the use of hand-hose for the purpose of irrigation; bad plumbing materials and bad plumbing work; and the steady run of water which is suffered in winter time to prevent freezing.

The above recited are leading and aggravated causes of waste, amounting, in the whole, to an alarming percentage of the total supply furnished by the city.

This amount of waste, which is believed to equal one-third of all the water supplied, can be reduced to only a moderate percentage by stringent regulations regarding the descriptions of water fixtures allowed, and the quality of work.

HOPPER WATER-CLOSETS.

January 1st, 1873, there were 16,137 of the different styles of these "hoppers" located within the premises of

water-takers. They are found in all classes of houses. In the best ones they are usually situated in the area under the sidewalk, or in back premises, exposed to frost, for the use of servants. The water is turned on in general by turning a crank, whereupon the water runs until turned off; and this turning off is precisely what is omitted, because, totally unlike the pan closet, — which must of necessity close when the hand is removed, — the water in the "hopper" flows on until the specific operation of turning the crank again is performed, which is very apt to be inadvertently, negligently, or willfully left undone.

SELF-ACTING WATER-CLOSETS.

Under this head are 209 self-acting closets — that is to say, by opening a door or by seat-pressure. These allow a flow of water only when in use, consequently the liability to these being left open is less than with the plain hopper; but they require a much larger quantity of water than either the pan or self-closing closet. For instance, a family of seven persons, each one using the self-acting closet five minutes a day, thus 209 closets, calls for 36,575 gallons, daily; while the same service by pan or self-closing closets would call for but 5,872 gallons, or saving in favor of the "pan or self-closing" of 30,723 gallons per day.

The manifest economy of the pan or self-closing closet over the "hopper" is still more forcibly shown from the following cases, which the introduction of meter measurement has enabled the department to set forth accurately: —

Case No. 1.

Where there were five hopper closets supplied, in twelve months they consumed	1,088,750 gallons.
By substituting pan closets for these, the consumption for the same length of time was reduced to . .	384,831 "
Amount saved	703,919 "

Case No. 2.

Where there were three hopper closets supplied, in twelve months they consumed	1,255,470	gallons.
By substituting pan closets for these, the consumption for the same length of time was reduced to . .	19,859	"
Amount saved	1,235,611	"

Case No. 3.

Where there was one hopper closet supplied, in twelve months it consumed	554,780	"
By substituting a pan closet, the consumption for the same length of time was reduced to . . .	100,572	"
Amount saved	454,208	"

Case No. 4.

Where there were three hopper closets supplied, in twelve months they consumed	494,180	"
By substituting six pans for the three hoppers, for the same length of time, the consumption was reduced to	113,774	"
Amount saved	380,406	"

Case No. 5.

Where there was one hopper closet supplied, in twelve months it consumed	554,800	gallons.
By substituting one self-closing closet, for the same length of time, the consumption was reduced to . .	79,205	"
Amount saved	475,595	"

The result of the above five cases shows, in thirteen closets alone, a total saving of 3,249,739 gallons a year, or a daily saving of 685 gallons for each closet, at the same time affording all the needed service. In these cases meters are attached, and the water is doubtless shut off at night, showing, in part, that the great waste was in the working hours of the day. But for the meter, which compels the consumer to pay for all the water wasted as well as used, the estimate of loss above given would be more than doubled. Now, take the whole number of hopper closets, *i. e.*, 16,137, and assume what experience has shown to be within the actual fact, namely, that one closet in five is wasting water in the same ratio of the five cases cited, and the total waste will exhibit the amazing aggregate of 4,419,620 gallons in every twenty-four hours.

URINALS.

There are 2,152 public and private urinals located within the premises of water-takers; a very large proportion of this number are in manufactories, warehouses, stores and shops; they are constructed with no reference to economy in the use of water, having usually a constant flow of water by an one-eighth or one-half inch stream. It may be remarked here, that most of these urinals are constructed without reference to spreading the water over the surface of the

bowl, thus allowing the salt of urine to collect, rendering the bowl nearly as filthy as if no water was used.

HAND-HOSE.

During the past summer there were 1,318 hand-hose in use by Cochituate water-takers; of this number 638 were upon premises containing from 5,000 feet to five acres of land in the Roxbury and Dorchester districts. The season was a dry one, and gardens and grass land were freely watered by hand-hose in a manner and to an extent never contemplated as a use for hand-hose; besides, the rate of charges is in no way commensurate for such service, nor should it be allowed, if paid for.

The following table will show approximately to what a vast extent the Cochituate water must have been used for irrigation (the rain-gauge is also set down). It will be observed by this table that for the four months when the call for domestic use is largely reduced by the absence of housekeepers, the quantity of water consumed was some fifteen millions of gallons greater than during the first four months of the same year, when the city's inhabitants are at home and full domestic requirement is needed, together with the larger waste in cold weather.

Daily average consumption of water in 1873.

Ten months.	Gallons.	Rain-fall.
January,	17,639,100	6.69
February,	18,461,000	3.74
March,	15,983,700	4.54
April,	14,781,800	3.81
May,	17,637,400	4.92
June,	20,100,550	.65
July,	20,917,100	3.25
August,	19,544,600	6.46
September,	19,572,700	2.78
October,	17,113,800	5.43

There are other descriptions of water-fixtures which are objectionable in view of the economical use of water, but the waste by them is inconsiderable in comparison to those which are detailed above, and these can be greatly improved by attention to the last, now to be given, cause of waste, namely,

CHEAP AND DEFECTIVE FIXTURES.

These include a class of fixtures denominated in trade contract work. In most low-priced houses, and it is not always confined to those, plumbing is put in to bear tolerable inspection at exposed or readily seen parts, while elsewhere, as under the floors and partitions, the workmanship and materials used are of the poorest description; inadequate to bear water-pressure, or the occurrences which constantly threaten. Leaks presently appear, increasing more and more; then follow temporary expedients to put off thorough renewals; all the while a constant loss of water goes on. To remedy this evil, a sort of inquisitorial inspection was established a few years ago, but it became annoying to housekeepers, and it has proved inadequate to remedy so great an evil. Inspection and remedy should begin at an earlier period; early enough to prevent altogether the introduction of every kind of fixture or plumbing work which, in the experience of the Water Board, is liable to create waste from any cause whatever.

In several large cities inspection is made at the beginning with the best results. The cities of New York, Brooklyn, Albany, Philadelphia, Chicago, St. Louis, and elsewhere, require that before a plumber shall perform any service in a building where city's water is to be used, he shall be duly licensed. Among the requirements for such license are, that the applicant shall be a citizen of the United States, 21 years of age; that he shall furnish satisfactory certificates from at least two licensed plumbers of his regular practical

instruction in the business, and ought to be licensed; that a bond shall be required for faithful work; that no alteration or addition shall be made without notice to and consent of the respective water departments; that returns shall be made on the first of every month of work done calculated to increase or decrease the water-rate of the premises, also a return of all work put into newly-erected premises.

By means of such a comprehensive system, and to its rigid adherence which the system itself facilitates, water is not let on until all pipes, fixtures, and work, with their strength and arrangements, are approved. At this point the Registrar would respectfully say that, since the subject of waste in Cochituate water was first brought to the attention of the City Council by the Water Board in 1852, with similar mention in subsequent reports, he has made repeated attempts to do away with wasteful water-fixtures by recommending an increased rate of charge, but it was not the pleasure of the City Council to meet the subject in that form.

The total consumption of Cochituate water for the year 1872 was 5,498,141,000 gallons. Of this quantity 811,524,100 gallons was measured by meters. The question how much of the total supply was wasted cannot be accurately answered; but those best able to give an estimate set down the waste at a quantity equal to one-third of the whole supply.

The sale by meters does not entirely stop waste. This will appear by the annexed table, showing the consumption in the principal hotels by meter, and the amount shows little variation from what was used before meters were used. Manufactories would, doubtless, show the same fact. Hotels are taken, however, because their needed supply is more uniform. The table also exhibits the gain to the city pecuniarily by the use of meters. The whole number of meters now in use is 1,100, and it is owing to their introduction, even to this limited extent, that the increased revenue from

the sales of water has come to pass. It is to be regretted that the cost of this (smaller size) meter, $35 to $40, should prevent its general application.

Hotel Consumption of Water for 1872 *and previous Specific Rates.*

	Daily Consumption in gallons.	Specific rates.	Meter rates.
Revere House	20,612	$571 00	$2,257 09
Parker House	28,579	440 00	3,129 46
American House	17,404	810 00	1,905 79
Adams House	7,498	354 00	821 07
Tremont House	18,600	475 00	2,039 66
United States Hotel	12,329	672 00	1,350 11
Marlboro Hotel	7,306	262 00	800 05
Young's Hotel	8,206	250 00	898 59
Quincy House	9,667	426 00	1,058 53
	. . . .	$4,260 00	$14,260 35

The above figures prove the policy and the just gain to the city in charging by meter measurement, rather than by valuation as now prevails in regard to dwelling-houses, whose supplies taken from taps distributed over a house for manifold conveniences, hot and cold water with a constant flow into the drain, are charged no more than for the moderate quantity carried by hand from the tap, as formerly from pumps. Like all other acommodations, water should be paid for according to the quantity used, either by meter measurement or estimate, according to circumstances.

There are important considerations in this subject of waste besides the cost of water. It is of the first consequence for the department to know, with as much approximation as the subject admits, the quantity of water needed for all ordinary purposes, and this can be got at with sufficient accuracy; but the quantity of water beside this, which will be wasted

by the manifold ways and means for wasting, cannot be determined, even approximately. The reserve for large conflagrations cannot be calculated upon, but it must be provided. Another use is that for flushing the pipes, preventing improper accumulation therein, etc. Is it not wiser, then, to ascertain the legitimate need of the community from time to time, by stopping the opportunity to waste, rather than by large expenditures to seek to furnish all which can flow through the taps without looking as to the quantity required? These results can only be obtained by the introduction of the licensed plumbing system, and prescribing the quality and styles of water fixtures.

To illustrate the capricious (so to speak) uncertainty of waste, a comparison of the quantity of water consumed by similar departments of the city the past year will be quite pertinent. While all the institutions are suitably furnished with reference to good material and fixtures, helps to economy in the use of water, the police stations particularly should exhibit some degree of uniformity in their needs for water; but the facts are otherwise, and unaccountably so, for results prove that some pay proper regard to reasonable economy, while others do not.

Annual and Daily Consumption with Cost in some City Buildings for the year 1872.

	Daily Consumption.	Annual Consumption.	Amount paid.
City Hall	3,318	1,393.612	$418 08
Court House	12,212	4,454,684	1.336 40
City Hospital	27,063	9,878,106	2,963 43
Lunatic Hospital	9,195	3,356,301	1.006 89
House of Correction	20,413	7,450.950	2.235 28
Suffolk County Jail	4,570	1,668.059	500 41
Police Station No. 1.	1,311	478,687	143 60
" " 2.	762	278,223	83 46
" " 3.	1,791	654,000	196 20
" " 4.	764	278.595	83 57
" " 5.	817	318.925	95 67
" " 6.	489	178.815	53 64
" " 7.	1,494	545,616	163 68
" " 8.	488	178,290	53 48
" " 9.	327	120.428	36 12
" " 10.	839	306.598	91 97

There is one other important fact which deserves mention at this time. On July 20th, and October 5th, 1873, special observations were made, under the direction of the City Engineer, at Beacon Hill Reservoir, to determine the quantity of water used in a certain district of the city in the night, between the hours of one and three o'clock, A. M. (the data of each observation being on Sunday), and at a time when the consumption would be less than for any other two hours of the twenty-four.

The district observed upon was all that portion of the city north of Bedford, West, Park, Beacon and Charles streets, to the harbor and Charles river. The water was supplied exclusively from Beacon Hill Reservoir, with particular measurements made every fifteen minutes during

the two hours. The result was as follows, viz., July 20th, 386,857 gallons were drawn in the aforesaid two hours, which is equal to 4,642,284 gallons for twenty-four hours.

A thorough inspection was at once instituted upon all water-fixtures in this district, and they were put in order. These repairs, renewals, etc., etc., were completed October 5th, when the second observation was made with the following result, to wit: Between the hours of one and three o'clock, A. M., October 5th, 336,294 gallons were drawn in the aforesaid two hours, which is equal to 4,035,528 for twenty-four hours; showing a difference in the quantity of water drawn between the two experiments of 606,756 gallons.

The quantity of water drawn for legitimate uses at a point of time when these observations was made, *i. e.*, between one and three o'clock Sunday night, must be very limited, consequently the proper and reasonable deduction to be made from these figures is this, that with all the painstaking of the Board, a thorough inspection of the fixtures within the district during the period of seventy-five days, reduced the waste to a very inconsiderable quantity, *i. e.*, 606,756 gallons or 13 per cent., leaving the balance, viz., 4,035,528 gallons or 87 per cent. of the quantity drawn to be accounted for in no other way than by the use of improper fittings, objectional styles of water-closets and urinals previously referred to.

In view of all considerations upon the subject of waste, I would respectfully suggest the following: —

First, that the Water Board obtain authority to regulate all fixtures, so that no class of fixtures shall be in use, nor material or work furnished, excepting such as the Water Board shall approve.

Secondly, that the use of the hand-hose be suspended until sufficient water could be afforded for their general use.

Thirdly, that hopper water-closets and urinals be either abolished or their character changed by substituting the self-closing faucet for the now objectionable fixture.

Fourthly, that the water-rate for other objectionable styles of water-fixtures be charged at a rate commensurate with the quantity of water used and required.

From a recent personal inspection of the system regulating the use of water in other large cities, I am clear in the opinion that economy will be greatly promoted and the duties of the Water Department be greatly facilitated towards the end desired, if the system of licensing plumbers, with such other regulations as have been presented under this head above, shall be established.

Respectfully submitted,

WM. F. DAVIS,

Water Registrar.

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